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LAND MANAGEMENT - FIRE MANAGEMENT POLICIES, DIRECTIVES, AND GUIDES IN THE NATIONAL FOREST SYSTEM:

A REVIEW AND COMMENTARY

Richard J. Barney and David F. Aldrich

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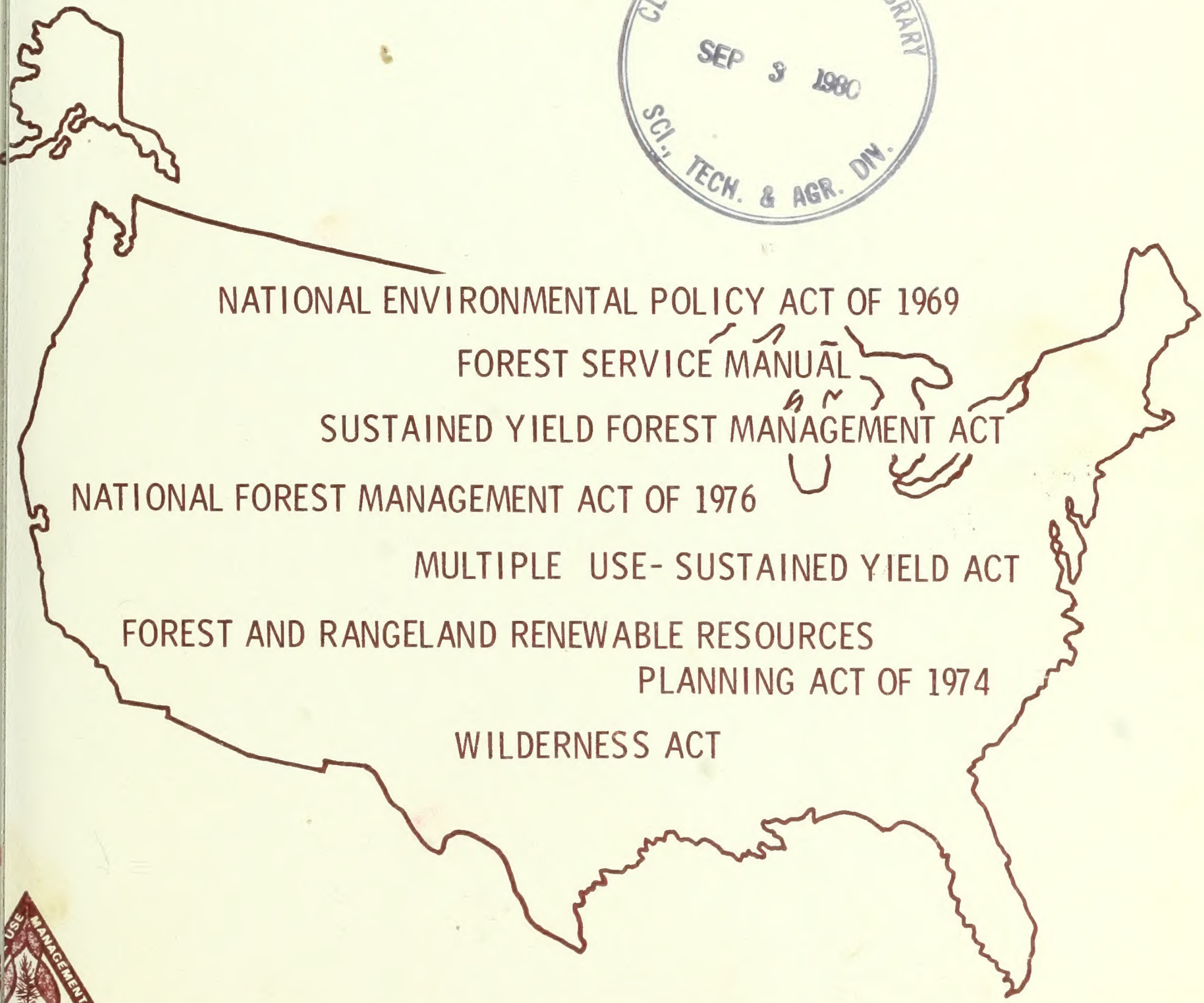
NATIONAL ENVIRONMENTAL POLICY ACT OF 1969
FOREST SERVICE MANUAL
SUSTAINED YIELD FOREST MANAGEMENT ACT
NATIONAL FOREST MANAGEMENT ACT OF 1976
MULTIPLE USE-SUSTAINED YIELD ACT
FOREST AND RANGELAND RENEWABLE RESOURCES PLANNING ACT OF 1974
WILDERNESS ACT

USDA FOREST SERVICE GENERAL TECHNICAL REPORT INT-76
INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

PREFACE

Since the analysis efforts on this paper were concluded, several major events have occurred that should be mentioned. First, a major change was made in Forest Service fire management policy. This revision allows variable fire suppression standards based upon land management objectives and values at risk. Second, the planning regulations for the National Forest Management Act have been issued. This action has resulted in a general change in both land management and fire management planning procedures, part of which are still being developed. Although these actions may date some of the review and comments in this paper, they do not negate their general worth as a historical perspective.

THE AUTHORS

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RESEARCH SUMMARY

Laws, regulations, manual supplements and other regional and forest guidance were reviewed for specific or implied references to fire management. Fire management was mentioned as far back as the Organic Act of 1897; however, in much of the material reviewed response to fire was implied, not stated. Specific direction was limited, and implementation processes were lacking. Stronger guidance is desirable at all management levels. This report interprets and comments on laws applicable to the Forest Service relative to fire; reviews policy; and traces the evolution of the concept of integrating fire considerations in land management planning.

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INTRODUCTION

Forest Service employees concerned with either wildfire or prescribed fire activities have brought about or witnessed a tremendous change in attitudes toward fire in managing lands. In less than a decade, the agency has modified its policy from one of strict fire protection to one of designing fire protection and fire use programs to meet land management objectives. To most people this change appears to have been comprehensive and relatively swift. Actually, no single piece of legislation triggered the change. In fact, the authors interpret legislation from the Organic Act forward as permitting current policies. Certainly, the perceptions of problems, capabilities for fire protection, and personalities of specific eras in the past resulted in the interpretation of laws and formulations of policies. Inertia tended to maintain the course. Advances in technology and knowledge, increases in fire protection capabilities, and a more general knowledge of wildland ecology in the last decade provided an environment favorable for the "new look" at fire.

The authors make no claim to having exclusive insight. This report is intended to interpret and comment on laws applicable to the Forest Service relative to fire, to review policy, and trace the rapid evolution of the concept of integrating fire into land management planning.

Information presented here is intended to provide Forest Service planners, fire managers, and others with a review and summary of legislation, policy, statements, and manual directives that are general to fire management. It is hoped that calling out and interpreting key statements will constitute another step toward truly integrating fire and land management planning.[1]

The perspectives and opinions relative to the material presented are those of the authors and are intended to stimulate comment and discussion. More detailed discussion of specific topics is certainly possible; however, we hope that this exposure will generate interest and questions that can be addressed in greater depth.

STUDY METHODS

Current Forest Service land management planning materials were obtained and reviewed. The Forest Service Manual, Section 8200 and amendments, was screened for fire and land management planning materials. Regional supplements to this section of the manual were obtained and screened. Special regional and forest planning guidance materials were also secured and reviewed as available.

Summaries of relevant policies, guidelines, and directives were developed. Narratives were prepared to discuss and comment on the implications of these directives. When necessary or appropriate, unique regional planning requirements were given special attention.

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[1] Barney, Richard J., and Rita P. Thompson. 1979. Fire and land management planning. Review draft. Intermt. For. and Range Exp. Stn., North. For. Fire Lab., Missoula, Mont.

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In addition to the above outlined material, pertinent Federal legislation was also reviewed for policy, direction, limitation, and guidance. Items that directly or indirectly addressed fire and land management were identified and discussed. Landmark legislation such as the Organic Act, the National Environmental Policy Act of 1969 (NEPA), the Clean Air Act, the Federal Water Pollution Control Act, the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) or amended Clean Air Act of 1976, and most recently the National Forest Management Act of 1976 (NFMA) were covered.

Review of these laws, policies, and other formal direction was conducted to identify those areas and places where specific impact on land management planning-fire management was either detailed or implied. Narrative summaries by type of document and categories of material found within were developed. Much of the initial review was done by the senior author.[2] The original effort has been reviewed and updated to include more recent laws, manual advice, and policy direction.

STUDY RESULTS AND DISCUSSION

Legislation

The following section presents laws and specific passages appropriate for inclusion in this report. Following each specific reference are comments as to the applicability and possible impact of the specific legislation noted. The basic sources for this information were found in USDA Forest Service Agricultural Handbook No. 453 and its Forest Service Supplement (USDA 1974b, 1976); Grad, *Environmental Law*, 1971; Schroth and Platter, *Nature, Law and Society*, 1974; and the statutes themselves.

Organic Administration Act of 1897.--Act of June 4, 1897 (30 Stat. 34, as amended; 16 U.S.C. 473-478, 479-482, 551). "The Secretary of Agriculture shall make provisions for the protection against destruction by fire and depredations upon the public forests and national forests . . . ."

The Forest Service must provide fire protection as an integral part of its management. Therefore management activities, including planning, must give major consideration to providing protection against destruction of fire. From a late 1970's perspective we recognize that the definition of "destruction" depends on management objectives. Fire size and the intensity of a fire are recognized as fire variables that, coupled with management objectives, determine whether or not a fire results in destruction. With this perspective, the mandate is not just to put out all fires. It requires land managers to prevent the occurrence of and to suppress fires that will result in destruction. Specifying management objectives and identifying fire prevention, presuppression, and suppression needs must be done in a planning exercise.

Clarke-McNary Act.--Act of June 7, 1924 (43 Stat. 653, as amended; 16 U.S.C. 471, 505, 515, 564, 565, 566, 567, 568, 569, 570).

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[2] Barney, Richard J. 1976. Land use planning - fire management relationships and needs in the U.S. Forest Service. Ph.D. dissert., Mich. State Univ., East Lansing. 244 p.

> Sec. 1. The Secretary of Agriculture is hereby authorized and directed, in cooperation with appropriate officials of the various States or other suitable agencies, to recommend for each forest region of the United States such systems of forest fire prevention and suppression as will adequately protect the timbered and cut-over lands therein with a view to the protection of forest and water resources and the continuous production of timber on lands chiefly suitable therefore (16 U.S.C. 564).
>
> Sec. 2. If the Secretary of Agriculture shall find that the system and practice of forest fire prevention and suppression provided by any State substantially promotes the objects described in the foregoing section he is hereby authorized and directed, under such conditions as he may determine to be fair and equitable in each State, to cooperate with appropriate officials of each State, and through them with private and other agencies therein, in the protection of timbered and forest-producing lands from fire . . . .
>
> Sec. 3. . . . investigate and promote practical methods of insuring standing timber on growing forests from losses by fire and other causes.

The last half of Section 1 bears a close look. Congress talks about "systems of forest fire prevention and suppression" that will "adequately protect" lands, with a goal of protecting forest and water resources and "continuous production of timber" on suitable lands. Our concept of fire prevention today encompasses a variety of approaches ranging from behavioral modification to engineering and fuel management. "Adequately protect" today can be construed to relate to identifying the reasonable risk that management is willing to assume. The last part refers to all forest resources, including a sustained supply of wood products, but from land suitable for production of those resources.

With today's perspective, the implication seems to be that Congress intended that values and land management objectives be tied to specific pieces of land and that the level of protection (prevention and suppression) applied be reasonable (cost effective). The Clarke-McNary Act is authorizing the Secretary to cooperate with others to support such systems of fire prevention and suppression on their lands, but it seems reasonable that Congress would expect the same concepts on Forest Service lands.

Although the Clarke-McNary Act is primarily one of cooperation with States in regard to fire, it does seem to indicate that the Forest Service must be aware of fire protection and its "state of the art." The Forest Service must be well versed in existing suppression systems as well as the needs of the ecosystems involved in order to determine what "adequate" protection is. This legislation certainly has an impact on fire management. As an indirect effect, there is an implication that the agency must be knowledgeable regarding fire. The net result is a clearer definition of fire and its place in the overall management spectrum.

McSweeney-McNary Act.--Act of May 22, 1928 (45 Stat. 699, as amended; 16 U.S.C. 581, 581a, 581a-1, 581b-581i).

> Sec. 1. The Secretary of Agriculture is hereby authorized and directed to conduct such investigations, experiments, and tests as he may deem necessary under sections 2 to 10 inclusive, in order to determine, demonstrate, and promulgate the best methods of reforestation and of growing, managing, and utilizing timber, forage, and other forest products, or maintaining favorable conditions of water flow and the prevention of erosion, of protecting timber and other forest growth from fire, insects, disease, or other harmful agencies, of obtaining the fullest and most effective use of forest lands, and to determine and promulgate the economic considerations which should underlie the establishment of sound policies for the management of forest land and the utilization of forest products: . . . .

Although not directly connected to land management planning and fire management, Congress recognized the need for research in the area of fire. Congress identified specifics in the areas of growing and producing forest, resources, protecting those resources from fire and biological forces, and determining economic considerations that should be part of setting "good management policies." The significance of economic considerations increases daily. Efforts are underway to develop management policies that integrate economic considerations of all management activities. This would force all resource management functions and service functions into a single land management planning exercise. It is this enabling legislation that provides for fire research, such as this report. Without this support we would be unable to develop the scientific basis for today's forest management. Establishment of fire research provides additional recognition for the relationships between land management and fire management activities. Such action gives formal support for fire as a part of management.

Sustained Yield Forest Management Act.--Act of March 29, 1944 (58 Stat. 132, as amended; 16 U.S.C. 583-583i).

> Sec. 1. In order to promote the stability of forest industries, of employment, of communities, and of taxable forest wealth, through continuous supplies of timber; in order to provide for a continuous and ample supply of forest products; and in order to secure the benefits of forests in maintenance of water supply, regulation of stream flow, prevention of soil erosion, amelioration of climate and preservation of wildlife. . . .

Although not explicitly stated in the above passage, it appears implicit that adequate steps in protection as well as all other phases of fire management must be taken to meet the obligations of this act. Such terms as continuous, ample, maintenance, prevention, amelioration, and preservation all indicate that forethought, planning, and care are "musts" in the management of our forest resources. Implied here is indeed a need to integrate fire and land management planning. Without such a "marriage," it does not appear that the legislative conditions can be met.

Cooperative Forest Management Act.--Act of August 24, 1950 (64 Stat. 473, as amended; 16 U.S.C. 568c, 568d).

> Sec. 1. The Secretary of Agriculture is hereby authorized to cooperate with State foresters or appropriate officials of the several States, Territories, and possessions to provide technical services to private landowners, forest operators, wood processors, and public agencies, with respect to the multiple use management and environmental protection and improvement of forest lands, the harvesting, marketing, and processing of forest products, and the protection, improvement and establishment of trees and shrubs in urban areas, communities, and open spaces.

Here again, although the above act revolves around cooperation, it seems to be implicit that fire management-land management planning relationships must be considered. Without a thorough understanding of the management-fire ties, one cannot provide technical services "with respect to multiple use management and environmental protection and improvement of forest lands . . . and their protection . . . ." It is important to know where fire and land management planning, along with the eventual application and implementation, go together.

Forest Service Omnibus Act of 1958.--Act of June 20, 1958 (72 Stat. 216; 16 U.S.C. 502, 554b, 555, 556, 556b, 556c, 565b, 579c, 580f).

> Sec. 5. The Secretary is authorized, subject to such conditions as he may prescribe, to transfer, without reimbursement or at such prices and upon such terms as he may impose, to States and political subdivisions of agencies thereof fire lookout towers and other structures or improvements used by the Forest Service for fire prevention or suppression purposes, and the land used in connection therewith if such land is outside national forest boundaries, when they are no longer needed for such purposes . . . .

Before one can determine whether fire management is needed or not, he must have a thorough grasp of just where fire fits into the overall management program. It is incumbent upon appropriate personnel to understand the needs and relationships. Without this understanding, decisions are made primarily from the position of fire control and prevention for fire control and prevention's sake. Therefore, one truly must have a perspective on land management and fire relationships.

Multiple Use-Sustained Yield Act.--Act of June 12, 1960 (74 Stat. 215; 16 U.S.C. 528-531).

> Sec. 4. As used in this Act, the following terms shall have the following meanings:
>
> (a) "Multiple use" means the management of all the various renewable surface resources of the national forests so that they are utilized in the combination that will best meet the needs of the American people; making the most judicious use of the land for some or all of these resources or related services over areas large enough to provide sufficient latitude for periodic adjustments in use to conform to changing needs and conditions; that some land will be used for less than all of the resources; and harmonious and coordinated management of the various resources, each with the other, without impairment of the productivity of the land, with consideration being given to the relative values of the various resources, and not necessarily the combination of uses that will give the greatest dollar return or the greatest unit output.
>
> (b) "Sustained yield of the several products and services" means the achievement and maintenance in perpetuity of a high-level annual or regular periodic output of the various renewable resources of the national forests without impairment of the productivity of the land. (16 U.S.C. 531)

The above act, especially 4(b), requires that fire be considered in land management planning and resulting management activities. Fire can enhance or reduce the level of specific resources, depending on the timing, location, and characteristics of fires. Management strategies and resulting activities change behavior of fires, and the effort and costs required to suppress fires. These factors must be assessed relative to their social and ecological acceptability when writing short- and long-range management plans.

National Forest Roads and Trails Systems Act.--Act of October 13, 1964 (78 Stat. 1089; 16 U.S.C. 532-538).

> Sec. 1. . . . to provide for intensive use, protection, development, and management of these lands under principles of multiple use and sustained yield of products and services. (16 U.S.C. 532)

> Sec. 4. The Secretary is authorized to provide for the acquisition, construction, . . . in locations and according to specifications which will permit maximum economy in harvesting timber . . . and at the same time meet the requirements for protection, ...

Even legislation regarding roads relates to protection, which in turn can be related to fire and fire management. If one is to consider "maximum economy in harvesting timber . . . and at the same time meet the requirements for protection," then certainly there must be an understanding of fire management-land management relationships.

Wilderness Act. --Act of September 3, 1964 (78 Stat. 890; 16 U.S.C. 1131-1136).

> Sec. 2(c). A wilderness in contrast with those areas where man and his own works dominate the landscape, is hereby recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain. An area of wilderness is further defined to mean in this act an area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature with the imprint of man's work substantially unnoticeable. . . .

> Sec. 4(d)(1). . . . In addition, such measures may be taken as may be necessary in the control of fire, insects, and diseases, subject to such conditions as the Secretary deems desirable.

The fire management implications of the Wilderness Act have been thoroughly discussed during the last decade. Congress described wilderness as an area where natural influences are to dominate those of man (Sec. 2(c)). In Section 4(d)(1) the Secretary of Agriculture is given the authority to identify fire control measures that may be necessary. To provide the management direction and supporting programs required by the Act, requires an evaluation of fires and prescriptions for handling them.

Congress allowed the land manager to prescribe the mix of fire use and fire suppression appropriate for each wilderness.

This act has recently attracted special interest, because under certain conditions fires have been "allowed to burn" in wildernesses under a special exception to the Forest Service 10 a.m. policy. A special opinion from the Office of the General Counsel held that the Forest Service exceptions are reasonable and legal. The General Counsel specifically referenced the above section of this act.[3] This decision, although not a court-set precedent, may well have far-reaching implications with regard to land management planning and fire management.

---

[3] Fowler, Richard L. 1975. 10 a.m. fire control policy exceptions. Letter (5130 Suppression) to John R. McGuire, Chief, USDA Forest Service.

Wild and Scenic Rivers Act.--Act of October 2, 1968 (82 Stat. 906; 16 U.S.C. 271-1287).

> Sec. 10(a). Each component of the national wild and scenic rivers system shall be administered in such manner as to protect and enhance the values which caused it to be included in said system without, insofar as is consistent therewith, limiting other uses that do not substantially interfere with public use and enjoyment of these values. In such administration primary emphasis shall be given to protecting its esthetic, scenic, historic, archeologic, and scientific features. Management plans for any such component may establish varying degrees of intensity for its protection and development, based on the special attributes of the area.

The above section of this act could also have implications regarding land use lanning and fire management. Although protection is the primary emphasis here, the hrase, ". . . enhance the values which caused it to be included in said system. . ." pens the door for other than a strict protectionist point of view relative to planning nd fire management. Fire could indeed play an important role in the "protection and evelopment" of a specific area.

National Environmental Policy Act of 1969.--Act of January 1, 1970 (P.L. 91-90); (83 Stat. 852; 42 U.S.C. 4321, 4331-4335, 4341-4347). The National Environ-ental Policy Act (NEPA) has perhaps had more impact on management activities of the orest Service than any other legislation since its beginning over 70 years ago. ection 102 of this act, reproduced in part below, has probably the most direct effect.

> Sec. 102. The Congress authorizes and directs that, to the fullest extent possible: (1) the policies, regulations, and public laws of the United States shall be interpreted and administered in accordance with the policies set forth in this Act, and (2) all agencies of the Federal Government shall--
>
> (A) utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decisionmaking which may have an impact on man's environment;
>
> (B) identify and develop methods and procedures, in consultation with the Council on Environmental Quality established by title II of this Act, which will insure that presently unqualified environmental amenities and values may be given appropriate consideration in decisionmaking along with economic and technical considerations;
>
> (C) include in every recommendation or report proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on--
>
> (i) the environmental impact of the proposed action,
>
> (ii) any adverse environmental effects which cannot be avoided should the proposal be implemented,
>
> (iii) alternatives to the proposed action,
>
> (iv) the relationship between local short term uses of man's environment and the maintenance and enhancement of long-term productivity, and

> (v) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.
>
> Prior to making any detailed statement, the responsible Federal official shall consult with and obtain the comments of any Federal agency which has jurisdiction by law or special expertise with respect to any environmental impact involved . . .
>
> (D) study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources . . .
>
> (G) initiate and utilize ecological information in the planning and development of resource-oriented projects; . . .

Section 102 of NEPA certainly spells out what must be done for any major Federal action. Major Federal action has been interpreted to include the planning process itself. It should also be clear that any major use of fire regardless of the purpose must fall into the identification and review process set forth. Alternatives and consequences of fire use must be discussed in depth. This in turn requires a thorough understanding of the process and its effect on the system. Interdisciplinary aspects and integration of natural and social sciences is also an important consideration.

Environmental Quality Improvement Act of 1970.--Act of April 3, 1970 (83 Stat. 852; 42 U.S.C. 4371-4374).

> . . . (d) In carrying out his functions the Director shall assist and advise the President on policies and programs of the Federal Government affecting environmental quality by--. . . .
>
> (2) assisting the Federal agencies and departments in appraising the effectiveness of existing and proposed facilities, programs, policies, and activities of the Federal Government, and those specific major projects designated by the President which do not require individual project authorization by Congress, which affect environmental quality;
>
> (3) reviewing the adequacy of existing systems for monitoring and predicting environmental changes in order to achieve effective coverage and efficient use of research facilities and other resources;
>
> (4) promoting the advancement of scientific knowledge of the effects of actions and technology on the environment and encourage the development of the means to prevent or reduce adverse effects that endanger the health and well-being of man;
>
> (5) assisting in coordinating among the Federal departments and agencies those programs and activities which affect, protect, and improve environmental quality; . . . .

This act takes additional steps, beyond NEPA, to insure environmental quality. It attempts to insure implementation of environmental quality policies already established. Here, due to feedback to the President, support or control is perhaps more probable. As in the other cited acts, this, too, has important impacts on land management planning and fire management relations.

Clean Air Act of 1963 as amended. P.L. 88-206.--Considering State regulations now in effect under this act, this is indeed important to land use planning and fire management. Existing and planned use of fire comes under the regulatory powers of this act. Depending upon local application, fire use can be heavily restricted. Under this act States have regulatory powers over *all* agencies regarding air quality matters.

Federal Water Pollution Control Act Amendments of 1972.--(86 Stat. 816; 33 U.S.C. 1251). As in the Clean Air Act above, this legislation can have serious implications relative to fire. Contemplated extensive use of fire in planning and practice could also be affected by this act amendment. In turn, this would affect the fire-planning relationship in some situations.

Forest and Rangeland Renewable Resources Planning Act of 1974.--Act of August 17, 1974 (88 Stat. 476; 16 U.S.C. 1601-1610). This act may well come to have as much or more impact on the Forest Service management system as did NEPA. Although it is a little early to completely assess such impact potential, the requirements of this act could well exceed the time and energy currently required to comply with NEPA. The Resource Planning Act (RPA) states in part:

> Sec. 2. . . . The Assessment shall be prepared not later than December 21, 1975, and shall be updated during 1979 and each tenth year thereafter, and shall include but not be limited to-- . . . .
>
> > (2) an inventory, based on information developed by the Forest Service and other Federal agencies, of present and potential renewable resources, and an evaluation of opportunities for improving their yield of tangible and intangible costs and direct and indirect returns to the Federal Government;
>
> Sec. 3. The Program shall include, but not be limited to--. . . .
>
> > (2) specific identification of Program outputs, results anticipated, and benefits associated with investments in such a manner that the anticipated costs can be directly compared with the total related benefits and indirect returns to the Federal Government;
>
> Sec. 5 (b). In the development and maintenance of land management plans for use on units of the National Forest System, the Secretary shall use a systematic interdisciplinary approach to achieve integrated consideration of physical, biological, economic, and other sciences.
>
> Sec. 8. NATIONAL FOREST SYSTEM PROGRAM ELEMENTS.--The Secretary of Agriculture shall take such action as will assure that the development and administration of the renewable resources of the National Forest System are in full accord with the concepts for multiple use and sustained yield of products and services as set forth in the Multiple-Use Sustained-Yield Act of 1960. To further these concepts, the Congress hereby sets the year 2000 as the target year when the renewable resources of the National Forest System shall be in operating posture whereby all backlogs of needed treatment for their restoration shall be reduced to a current basis and the major portion of planned intensive multiple-use sustained-yield management procedures shall be installed and operating on an environmentally-sound basis.

> Sec. 9. TRANSPORTATION SYSTEM.--The Congress declares that the installation of a proper system of transportation to service the National Forest System, as is provided for in Public Law 88-657, the Act of October 13, 1964 (16 U.S.C. 532-538), shall be carried forward in time to meet anticipated needs on an economical and environmentally sound basis . . . .

Upon reviewing the above-quoted segments of this act, it appears implicit that fire is one of the serious considerations. Fire can be considered both from the control and use standpoints. The establishment of multiple use objectives, interdisciplinary approach, and transportation systems imply the consideration of fire both as a management tool and from the perspective of protection and that it should be viewed from a total land management context.

National Forest Management Act of 1976.--(90 Stat. 2949; 16 U.S.C. 1600). This act (NFMA) has been cited by many as a milestone and landmark legislation relative to Forest Service programs. A major part of the Act is devoted towards strengthening the Forest and Rangeland Renewable Resources Planning Act (RPA). One of the major points of the Act is the direction relative to land-management planning. Section 6 of the Act is directed at "National Forest System Resource Planning". This section states:

> Sec. 6(f). Plans developed in accordance with this section shall--
>
> > (3) be prepared by an interdisciplinary team. Each team shall prepare its plan based on inventories of the applicable resources of the forest;
> >
> > (g)(2) specifying guidelines which--
> >
> > (C) provide for methods to identify special conditions or situations involving hazards to the various resources and their relationship to alternative activities:
> >
> > (3) specifying guidelines for land management plans developed to achieve the goals of the Program which--
> >
> > (A) insure consideration of the economic and environmental aspects of various systems of renewable resource management, including the related systems of silviculture and protection of forest resources, to provide for outdoor recreation (including wilderness), range, timber, watershed, wildlife, and fish:
> >
> > (C) insure research on and (based on continuous monitoring and assessment in the field) evaluation of the effects of each management system to the end that it will not produce substantial and permanent impairment of the productivity of the land;
> >
> > (h)(3)(i) Resource plans and permits, contracts, and other instruments for the use and occupancy of National Forest System lands shall be consistent with the land management plans. Those resource plans and permits, contracts, and other such instruments currently in existence shall be revised as soon as practicable to be made consistent with such plans. When land management plans are revised, resource plans and permits, contracts, and other instruments, when necessary, shall be revised as soon as practicable . . . .

Section 6(f)(3) states the requirements for interdisciplinary planning team. Fire specialists should indeed be part of the special inputs to a planning team, which is confirmed by Sec. 6(g)(2)(C). Fire specialists must assist in specifying guidelines relative to fire hazards. Furthermore, this segment is in reality a legal justification and direction for integrating fire into land management planning. Additional support for fire inputs can be found in Sec. 6(g)(3)(A), which concerns protection. Even research is directed to evaluate the effects of each management system relative to productivity. Fire should certainly be an input in this endeavor. One final justification for the integration of fire into land management planning is in Sec. 6(h)(3)(i) where, "Resource plans . . . and other instruments . . . shall be consistent with land management plans". This section indicates that various fire management plans be tied to and a service for the more general land management plan. The thrust of this entire act certainly supports the integration of fire into the general land management planning process.

A more recent response to the NFMA and the sections referenced above can be found in a task force draft report.[4] This report outlines an array of actions needed to comply with the legistative requirements. Although the document does not spell out how the job is to be accomplished, it does identify necessary inputs. Specific procedures on how to implement such direction are expected. This report shows that fire is to become a part of general planning.

Generally, the legislation discussed above can affect fire management and the planning process. In the more recent legislation, some specific questions may have to be decided in the courts before applications can be made. Managers must be aware of the legal constraints, and not exceed statutory authority. Much of the direction in respect to fire management and planning is implied and requires additional interpretation and guidance. The Forest Service Manual discussed in the following pages is one method of interpreting and applying legislation.

Forest Service Manual and Guidance

The Forest Service Manual (USDA 1975c, Sec 8200) offered only limited instruction on integrating fire considerations into land management planning. The initial reference was found in FSM 8213-9, Functional Planning. Here the manual states that functional plans such as Forest Fire Protection Plans "*will* be coordinated within the overall direction of forest plans. Forest functional plans also provide guidance to providing information on present levels and methods of management".

This section of the manual goes on to state that:

> Functional plans thus help establish current production and potential goals for planning units. Functional plans will contain the technical specifics on the activities and projects that implement planning decisions . . . . Functional plans are dependent upon land use plans for validity and basic land use allocation. Conversely land use plans depend upon responsive functional plans and projects for information and implementation . . . .

Chapter 8220, National Forest System Land Use Planning Procedure, goes into onsiderable detail on the planning hierarchy and general procedures. Main topics overed are Planning Area Guides, Management Zones, Forest Land Use Plan, Forest

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[4] U.S. Department of Agriculture, Forest Service. 1978. Fire considerations in Forest planning - a fire management proposal. Fire in Land Management Planning Task Force, Washington, D.C. Working Draft No. 2. 46 p. mimeo.

Coordinating Requirements, Planning Units, Maintenance, Availability, and Graphics. Primarily the general "what" is outlined with a variety of items to consider enumerated. The specific "how" is apparently left to the planner's discretion. Although lack of detailed instructions is not necessarily bad it can waste time and result in nonuniform plans.

The first specific mention of fire comes under FSM 8226.2, Priority of Study for Planning Units, which enumerates criteria for determining study priorities. The last item in the list is: "Critical need to reevaluate fire, insect, and disease protection." Fire therefore is one factor to consider in establishing which planning unit to study. A following section, FSM 8226.41, includes the next reference to fire: "In order to develop a series of alternative management plans for a Planning Unit, one of the basic requirements is a knowledge of what things are available to work with or use." The section covers additional points about planning and information. It is specifically stated that:

> A search of existing data sources should always be made before starting field inventory projects . . . . Following are a number of data sources useful in developing a complete inventory for planning.
>
> . . . f. Fire Prevention Plans
> . . . h. Preattack fire plans
> . . . k. Historical records used as:
>
> . . . (1) Fire occurrence maps
> . . . (4) Fire weather records

The foregoing items are the only explicit references to fire in Section 8200 of the Manual. However, one might consider fire implicit in FSM 8226.42, Environmental Potential: ". . . An understanding of the biological system with its inherent opportunities and constraints in producing needed products and outputs is basic to planning . . ." Here, fire as an ecological consideration, and the inclusion or exclusion of fire relative to management might be considered and integrated. How the latter is to be accomplished is still, at this point, a moot question.

The consideration of fire might further be covered in the process of alternate plan formulation and analysis as covered under FSM 8226.6 and FSM 8226.7, respectively. Here, too, no specific process is outlined, and any fire inclusion is apparently the prerogative of the planner or planning team.

Before leaving policy and guidance at the national level it is appropriate to cover fire plans mentioned earlier. In FSM 5100, Fire Management, the need and general direction for fire control and fire planning are outlined. Section FSM 5102, Objectives, includes the following statements:

> The overall objective for fire management is to provide a fire protection and use program which is responsive to land and resource management goals and objectives.
>
> Regional Foresters shall:
>
> 1. Provide a balanced fire management program which is cost effective and commensurate with threats to life and property, public safety, values, hazards, risks, and resources output targets.
>
> 2. Provide for prescription fire using either planned or unplanned ignitions to protect, maintain, and enhance production of National Forest resources.

3. Provide data, information, and coordination for full integration of fire use and protection in the development, analysis, and evaluation of alternative land management prescriptions, goals, and objectives.

In the next section 5103, the reviewed policy is stated as follows:

> Policy. The basic fire management policy on National Forest System Lands is to provide well-planned and executed fire protection and fire use programs that are cost effective and responsive to land and resource management goals and objectives and supportive of RPA outputs.

In the sub-headings under policy more explicit ties between fire and land management are enumerated.

5103.1 Land Management Coordination. Forest Supervisors, in developing alternative land management prescriptions, objectives, and goals, shall:

1. Develop fire management objectives through interdisciplinary staff, line officer, and cooperator interaction.

2. Utilize appropriate fire management skills.

3. Analyze and evaluate effects of fire use and protection on resource outputs.

Regional Foresters will establish procedures to monitor, analyze, and evaluate fire management programs.

5103.2 Fire Management Areas. The use of fire management areas is extended to provide for an orderly transition from the current fixed protection objectives to interim fire management area objectives. Ultimately, fire management objectives will be developed through the land management planning process.

For each fire management area, Forest Supervisors shall determine objectives that include: (1) the standard of fire protection and fire use necessary to ensure that land management goals and objectives can be met, (2) measurable standards, such as, the maximum individual fire size, and tolerate annual and long-term allowable burned acreage, for established fire intensity levels, and (3) as appropriate, areas for treatment by prescription fire and a schedule for the required maintenance of these areas.

5103.3 Requirements. When developing fire management objectives and areas, Forest Supervisors shall:

1. Be responsive to existing land management goals and objectives.

2. Provide for interdisciplinary and cooperator involvement.

3. Utilize the environmental analysis process (FSM 1950).

4. Be responsive to the letter and intent of applicable laws and regulations.

5. Emphasize protection from threats to life, property, and public safety.

6. Provide for written agreement with affected cooperating landowners and agencies.

7. Emphasize economic considerations and provide for a cost-effective program consistent with management objectives.

The above-quoted segments certainly begin to tie fire and land management together. There is clear indication that the role of fire management is a function of management needs. This most recent manual revision ties well to the fire management-land management planning interface. These policy revisions provide a strong basis to develop procedures for actual implementation.

The Fuel Management chapter provides additional implicit support for integrating fire and land management planning. Under objectives, 5150.2, we find the following:

> The objective of fuel management is to obtain fuel conditions which permit protection forces to meet fire control objectives established to ensure a sustained, high level of productivity of renewable resources, using methods which maintain environmental quality.

It would seem necessary here that to meet this objective, fire and land managers must coordinate activities. The land management planners and the fire managers must go through series of give-and-take sessions to arrive at workable plans. Land managers must state their needs and fire managers the resultant requirements. Eventual resolution will provide the viable action. It would appear, however, that both parties would benefit from an objective procedure that would assist them in developing the rationale for the decisions made.

Finally, in the last chapter of this section of the Manual, 5190, Management, we come to National Fire Planning. Objectives 1 and 2 quoted in part, are as follows:

> 1. To study scientifically the needs and application of fire control . . . .
>
> 2. To provide nationwide fire control performance standards to meet current resource management objectives . . . .

Here again is additional direction and support for fire managers and land managers to get together to plan. Obviously, integration of various phases of planning is authorized. Perhaps the problem lies not in the "what to do" but the "how to do it." Even though the general direction exists, the specific direction for implementation either does not, or it is relatively weak at this time. Management is either reluctant to state specific "hows" or feels that doing so would constrain their options. In either case, the basic problem of integrating planning still exists.

Some additional advice has been provided through a publication entitled, "Fire Management Considerations for Land Use Planning" (USDA 1974a). This paper develops three basic questions relative to fire management:

> How does fire relate to the ecosystem within and adjacent to the unit of planning?
>
> In terms of the above considerations, are the management alternatives being prepared really viable?
>
> Given some viable management alternatives, what is the appropriate fire management direction?

The stated main objective of this publication is to ". . . facilitate the preparation of high quality and meaningful land use plans . . .. None of the individual 'considerations' are to be construed as management directions." The paper is divided into the six RPA resource systems: land and water; timber; recreation and wilderness; range; wildlife and fish; and human and community development. Following each of these headings is a list of actions one could take, presumably in the planning process. But the publication does not seem to have a definite goal. Nor does it outline a process for systematic planning, let alone specific instructions for answering all the questions or accomplishing all the tasks. It does provide questions that may be relevant to a specific planning situation. However, there is need for a systematic approach to the problem to ensure objectivity and thoroughness. The material has been related to a fire management decision model which provides an additional perspective for application.[5]

Regional Manual Supplements and Advice

A Servicewide review of manual supplements in appropriate subject areas, planning and fire management, has provided additional perspective. Because of the constantly changing nature of this level and type of guidance, it is not appropriate to discuss each Region's supplements. A general review illustrated with specific examples should suffice.

Few Regions had specific references to fire and land management planning in the 8200 section of the Manual. Many of the documents reviewed were draft materials that had not been made a part of the system, but influenced planning activities throughout this evolutionary period.

Several types of planning guidance have been prepared at the regional level. Although some of these documents may be in draft stage, they are used throughout the various Regions by field personnel. Region 1 developed one document which discussed in more detail the process of preparing unit plans (USDA 1963). Although the document did not specifically mention fire, fire inclusion could be implied in several areas. The most relevant Region 1 advice has been issued as an informal interim guideline and is entitled, "Fire Management in Land Use Planning" (USDA 1975a). This document goes beyond the very general guidance issued from the Washington Office and discussed earlier (USDA 1974a) and provides more specific guidance for the planning team. Although this advice was admittedly skeletal, the need for and desire to develop more detailed and specific guidance was recognized.

The Rocky Mountain Region did not have any FSM 8200 supplements that specifically ealt with fire. The supplement did, however, specify the use of the Region's multiple se guide (FSM 2100) until regional area guides were completed (USDA 1975b). In this anual amendment, fire implications were covered in the coordination checklist under he air pollution and fire headings in Sections 2141.4--8. The primary emphasis was n slash burning and smoke in the air pollution category. Under the fire heading, ire questions were listed covering prevention, hazard, protection level, and type onversion.

In transmitting the draft copy of the Washington Office "Fire Management Con-iderations for Land Use Planning" document, the Assistant Regional Forester for Fire n Region 2 made the following statement[6]:

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[5] Barney, Richard J., and Louis T. Egging. 1978. The relationship between "Fire anagement Considerations for Land Use Planning" (1974 Gray Book) and the Egging Fire considerations in Planning Model. Intermt. For. and Range Exp. Stn., North. For. ire Lab., Missoula, Mont. Office Rep. 19 p.

[6] Sanderson, E. J. Memorandum, Region 2, 8210(5100), Elements of Land Use lanning, to Forest Supervisor, April 15, 1974. 2 p. with attachments.

To bring the broad concept of fire management into our planning process will require:

1. Understanding of fire as a process in forest land ecosystems and its impact upon ecosystem components . . .

2. Integration of our understanding and knowledge of fire processes and effects with the management objectives of each specific land unit. Plans should detail how management objectives may be enhanced or aggravated by fire management . . .

3. Identification of proper fire management actions and constraints . . .

The Southwestern Region had no manual supplements in the FSM 8200 category that dealt with fire and land use planning. However, the Region did develop an extensive document relative to planning and decisionmaking methods and criteria.[7] This paper mentioned fire and fuels management in its discussion of inventory needs for planning. Throughout the remainder of this paper, one can infer that fire is or could be input in the various processes outlined. One might also infer that additional reference to fire might be included in inventory criteria for land use planning established in that Region. Regional planning personnel (Layser 1975) have documented their ideas for bringing fire considerations into management planning.

In mid-1975, land managers in the California Region presented a series of programs throughout the State to place land management planning in perspective (USDA 1975d). The sessions covered the entire spectrum of land management planning in the Region. One of the specific subtopics in the presentation centered around the relationship of fire planning to land management planning. A portion of the discussion covered the establishment of values and appropriate fire plans for protecting the resource and area involved. The managers noted that a land management alternative might not be feasible because of the cost of the necessary fire control. They did not cover, apparently, the application of fire as an integral management tool. This series of presentations, however, was an attempt at putting planning into perspective.

Although other Regions also developed advice to one extent or another, the few examples discussed above illustrate the general type of direction given. Today, most Regions are in the middle of developing new materials to support NMFA as well as the revised fire policy. The guidances will assist in the integration of fire and land management planning.

CONCLUSIONS AND RECOMMENDATIONS

The review of pertinent legislation and related agency guidance revealed several points. In respect to some of the legislation, there were several items that will affect land management planning-fire management relationships. These points were found as far back as the agency's Organic Act of 1897 and as recently as the National Forest Management Act of 1976. In much of the legislation reviewed, the consideration of fire management in combination with land management planning was implied. No lengthy or really specific guidance was found relative to the subject of integrating fire in land management planning.

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[7] Layser, Earle F. 1975a. Methods and criteria for a planning and decisionmaking process. USDA For. Serv., Southwest. Reg., Albuquerque, N.M. draft, 51 p.

The legislation reviewed can indeed restrict fire management and the planning process. Managers must be aware of the legal constraints to avoid exceeding their statutory authority.

The review of agency guidance, primarily the Forest Service Manual, in this specific area of planning did not reveal much direction other than in a broad context. No specific processes were found and much of the advice only enumerated items to consider or coordinate between functions. Even though general direction exists, the specific direction for implementation either does not exist or is relatively weak at this time. Regional manual supplements did not improve the specific direction to any great degree.

Although specific information and directives may be scarce, some planning teams have developed informal methods for identifying and integrating fire-land use planning relationships. Because of the current lack of unifying national direction on this and perhaps related topics, each planning level does what it perceives as best and most important. Resulting planning products provide a range from none to some material in regard to their consideration and integration of fire management. Several major efforts are currently underway to help resolve noted deficiencies.

Results of this report indicate that legislation, Servicewide manual guidance, regional manual supplements, and other related material lack specific direction for integrating fire management with land use planning. Before solid progress can be made, existing guidance must be more clearly interpreted, must become more specific, and must provide direction. Without such action, efforts toward fire management will lack uniformity and efficiency.

It is recommended that more centralized and stronger guidance be provided at all levels in land management planning, with emphasis on integrating fire management. In addition, clearer interpretation, specific processes, and more detailed management planning are necessary. A planning tool that would display consequences of management alternatives as they relate to fire over time would be desirable. This includes the effect of resource management on fire management strategies as well as the converse.

An interdisciplinary review team should be developed. This team would be responsible for reviewing legislation, policy, and guidelines relative to fire management and land management planning on a broader base than possible in this report. A result of such efforts would be a more comprehensive interpretation of existing guidance. In addition this team could prepare recommendations as to appropriate additions or deletions to existing direction in order to make it more relevant to today's management climate.

There needs to be an improved and generally understandable interpretation of the laws that relate to planning and fire management. Policies can then be changed or developed as a direct result of such clarification. Section 8200, 5100, 1200, and others in the Forest Service Manual can then logically be broadened to respond to policy changes and clarification. Servicewide, universal, planning processes should be developed which will utilize established constraints in developing management options and alternative strategies.

We must define what we (the public and the professional) want and need from our resource base. We must determine where we are headed in both the long and short run and how we are going to get there. The definition of objectives, clarification, and intensification of explicit direction does not exclude change. It does, however, provide a clearer, more definitive and duplicatable response on what we are intending in our management planning activities. Management options are not limited, but clarified. There will be management by directives rather than by default.

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KEYWORDS: fire, fire management, land management planning, policy, directives.

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FE ECOLOGY AND PRESCRIBED BURNING
THE GREAT PLAINS--A RESEARCH REVIEW

NRY A. WRIGHT ARTHUR W. BAILEY

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INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE

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FIRE ECOLOGY AND PRESCRIBED BURNING IN THE GREAT PLAINS--A RESEARCH REVIEW

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RESEARCH SUMMARY

Historical evidence indicates that fires were prevalent in grasslands. In the past, big prairie fires usually occurred during drought years that followed 1 to 3 years of above-average precipitation, which provided abundant and continuous fuel. Fire frequency probably varied from 5 to 10 years in level-to-rolling topography and from 15 to 30 years in the rougher, dissected topography containing rough breaks and rivers.

This paper contains basic ecological information, vegetative descriptions, and fire effects data for the shortgrass, mixed grass, and tallgrass prairies in the southern, central, and northern Great Plains. In the appendix, fire effects data have been tabulated for each species for quick reference. Prescription guides are provided for all major vegetation types where prescribed burning data have been collected.

In the shortgrass prairie, grasses do not benefit from prescribed burning, but fire can be used to clean up uprooted brush, kill small juniper, and kill cactus. Prescribed fire has a wider variety of uses in the mixed and tallgrass prairies, particularly if the burns are conducted following winters with above-average precipitation. Major benefits of prescribed burning are to control undesirable shrubs and trees, burn dead debris, increase herbage yields, increase utilization of coarse grasses, increase availability of forage, improve wildlife habitat, and to control exotic, cool-season grasses. Often, several objectives can be achieved simultaneously.

Prescribed fire frequency should not be more often than 5 to 8 years in a 20-inch (51-cm) precipitation zone but can be as often as 1 to 3 years in a 35- to 40-inch (89- to 102-cm) precipitation zone. Good soil moisture in the upper 1 ft (0.3 m) of soil is especially important before conducting a prescribed burn if the goal is to increase yield and palatability of forage. If control of shrubs is the primary consideration, such as in juniper country, burning during drought years may have the best long-term effect.

To use prescribed fire is not as dangerous as most people think, providing it is done by experienced personnel. We recommed a minimum of 2 years of prescribed burning experience under a range of weather conditions for individuals having major supervisory responsibilities. Moreover, we recommend that supervisors be trained in planning and conducting burns and in evaluating the weather. To achieve a desired effect and for safety, one must have the skill to recognize, and the patience to wait for favorable weather.

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INTRODUCTION

The historical prevalence of fire in grasslands cannot be denied (Fidler 1793; ss 1932; Sauer 1944; Stewart 1951, 1953; Dix 1960; Humphrey 1962; Jackson 1965; lson and England 1971; Kirsch and Kruse 1972; Seevers and others 1973). For example, e diary of Fidler (1793), who observed fires in the fescue grassland of southwestern berta, contains these statements:

> "These large plains either in one place or another is constantly on fire and when the grass happens to be long and the wind high, the sight is grand and awful, and it drives along with amazing swiftness. The lightning in the spring and fall frequently lights the grass, and in winter it is done by the Indians." And later, "These fires among the long grass is very dangerous."

though lightning caused many fires (Haley 1929; Komarek 1966) and the Indians set me (Nelson and England 1971; Heady 1972), most documented conflagrations of the ortgrass prairie in the late 1880's were the result of carelessness by trail out-ts, cowboys, and cooks (Haley 1929). Today, dry lightning storms and man are the jor causes of fire in grasslands. Regardless of origin, fires have always been mmon and widespread on prairies during drought years.

In the semi-arid areas, big prairie fires in the past usually occurred during ought years that followed 1 to 3 years of above-average precipitation, which pro-led abundant and continuous fuel. Consequently, wildfires traveled for many miles n) when the winds and air temperatures were high and relative humidity was low. An ample is an account of a fire (Haley 1929) that started in the fall of 1885 in the kansas River country of western Kansas. It jumped the Cimarron River, burned across e North Plains of Texas, and did not stop until it reached the rugged Canadian River eaks, a distance of 175 miles (282 km). A million acres (404 854 ha) of the XIT nch alone burned in Texas. Haley (1929) gave several other accounts of large fires) by 60 miles (32 by 97 km)] on the High Plains of Texas.

Many grassland fires still start during dry weather, but they do not travel as far as in the past. Cultivated land breaks up the continuous grass cover of the prairie. One of the largest fires observed by the senior author in the Texas-New Mexico area was started by a broken powerline in Lea County, N.M., in April 1974. Win was 55 miles (89 km)/h, relative humidity was 5 percent, and air temperature was 100°F (38°C). Herbaceous growth from the previous year was abundant. The fire traveled 26 miles (42 km), burning 52 sections (13 474 ha), and crossed three major highways. It was finally stopped by a plowed field. This typifies the prairie fires of today and the conditions under which they will travel long distances.

FIRE HISTORY OF THE PRAIRIE GRASSLANDS

There are no reliable historical records of fire frequencies in prairie grassland because there are no trees to carry fire scars from which to estimate fire frequency. However, we know that fire frequency was high because explorers and settlers were concerned about the danger of prairie fires. We can extrapolate fire frequency data for grasslands from forests having grassland understories such as ponderosa pine (*Pinus ponderosa*) in the West and longleaf pine (*Pinus palustris*) in the Southeast. A variety of sources (Chapman 1926, 1944; Weaver 1951; Wagener 1961; Hall 1976; Arno 1976) indicate that fire frequency in pine forests varied from 2 to 25 years. Because prairie grassland is typically of level-to-rolling topography, a natural fire frequenc of 5 to 10 years seems reasonable. In topography dissected with breaks and rivers, such as the Rolling Plains and Edwards Plateau of Texas, fire frequency may have been 20 to 30 years. The latter assumption is based on historical accounts by Marcy (1849) of large honey mesquite (*Prosopis glandulosa* var. *glandulosa*) trees in the Rolling Plains, and the frequency of fire that we know is necessary to keep large Ashe juniper trees (*Juniperus ashei*) out of prairies in the Edwards Plateau (Wink and Wright 1973).

How important have fires been in maintaining grasslands? Stewart (1951, 1953) and Sauer (1944) proposed that treeless grasslands are a product of repeated fires set by aborigines. Wedel (1957) and Hastings and Turner (1966) make a strong case for climate being the primary influence on American grasslands. Winter rainfall decreases rapidly from the Southeast to the center of the United States. Snowfall decreases rapidly from the eastern edge of the Rockies to the Southwest and across the northern margin of the Great Plains, making this area unsuitable for tree growth (Wedel 1957). Wells (1970) presented evidence that the origin and maintenance of grasslands is directly related to topography. He stated that the "rougher and more dissected the topography, the greater the former extent and the current spread of woody vegetation at the expense of grasslands."

Although we feel that climate is the dominant factor controlling North American grasslands, wide fluctuations in woody vegetation would occur if it was the *only* factor (Albertson and Weaver 1945; Bragg and Hulbert 1976). The impact of drought on the maintenance of grasslands has been illustrated by Albertson and Weaver (1945). They surveyed the mortality of natural trees, timber belts, old shelterbelts, and hedgerows following the drought of the 1930's. Their studies ranged from Oklahoma to Nebraska, and they recorded mortality rates ranging from 30 to 93 percent among the native deciduous trees [elm (*Ulmus* sp.), ash (*Fraxinus* sp.), hackberry (*Celtis occidentalis*)], and from 35 to 80 percent or higher among juniper.

On the eastern edge of the Great Plains "the balance between forest and grassland is so delicate that a little higher water content of soil, a slightly greater humidity, or protection from drying winds throws this balance in favor of tree growth, while the reverse conditions exclude it" (Albertson and Weaver 1945). Thus, there is good reason to believe that climate is the major factor in maintaining grasslands.

On level-to-undulating topography in the southern mixed prairie, drought (not necessarily severe), fire, insects, rodents, and competition from grass apparently interact to maintain grasslands. For example, in 1969 we burned mesquite trees that had been top-killed by herbicide in 1966. Of the 1,200 trees marked, 26 percent of them were killed over a 5-year period (Wright and others 1976a). Part of the mortality may be attributed to fire, but more than half of it seems to have resulted from the interaction of fire, a mild drought in 1970 and a severe one in 1971, insects, rodents, and competition from grass. A natural fire every 15 to 30 years in the southern mixed prairie could significantly reduce shrubs.

Shrubs and trees have always existed as scattered individuals or mottes on grasslands and along drainageways. In the Great Plains they are most abundant in the southern mixed prairie, mesic edge of the northern mixed prairie, eastern edge of the tallgrass prairie, and throughout the fescue prairie. Shrubs and trees are also present on rocky breaks or heavily grazed areas where fires are least frequent. Droughts can control shrub abundance where grass is healthy, but shifts from grasslands to shrubs and trees could occur on a 100-year cycle if vegetation was controlled solely by climate. Fire seems to have restricted shrub and tree growth in the past (Malin 1953), not so much as a single influence but in concert with other factors.

The restriction of shrub and tree growth by droughts, fire, and biotic factors did not eliminate trees in the southern mixed prairie nor on the eastern edge of the tallgrass prairie (Malin 1953). Open groves of large honey mesquite trees existed in the Rolling Plains of central Texas in 1849 (Marcy 1849). Historical evidence documents that these areas were subjected to fire (Michler 1850). Based on our experience, large honey mesquite and interior live oak (*Quercus virginiana*) trees are very tolerant of hot fires (crowns of trees remain alive), whereas trees less than 10 to 12 ft (3 to 4 m) tall can easily be top-killed. Thus, before the arrival of European man, one can easily surmise that it was feasible for a prairie fire to leave a mosaic of large trees, which left the appearance of a savanah, in the southern mixed prairie and the eastern tall grass prairie. Trees that were top-killed probably had a broad genetic base, as we will show in a later section, which permitted reburns to kill some trees and only suppress the resprouts of others.

Nonsprouting species such as Ashe juniper were more susceptible to fire. Wink and Wright (1973) have shown that hot fires could easily kill large juniper trees because of the volatility of the green material. Subsequent fires within 10 or 15 years could have killed the new juniper trees before they were old enough to produce seed, eliminating the potential local seed source of such a non-sprouting species. Thus, with occasional fires, such areas could easily have been converted to grasslands, with occasional patches of juniper on rocky sites. Protection from fire has favored the re-establishment of dense stands of juniper.

ECOLOGICAL CHARACTERISTICS AND EFFECTS OF FIRE

The vast North American Grassland lies between the Rocky Mountains and the eastern forest and extends from south-central Texas to the aspen-parkland in central Alberta and Saskatchewan (fig. 1). The grassland may be divided from west to east into the shortgrass, mixed, and tallgrass prairies, and grassland-forest combinations (Launchbaugh 1972). Because there is such a wide variation in species' combinations across the Great Plains, we will separate the area into the southern Great Plains, central Great Plains, and northern Great Plains. The northern Great Plains will include the aspen-parkland, a transitional zone of vegetation between the Great Plains grasslands and the Boreal Forest.

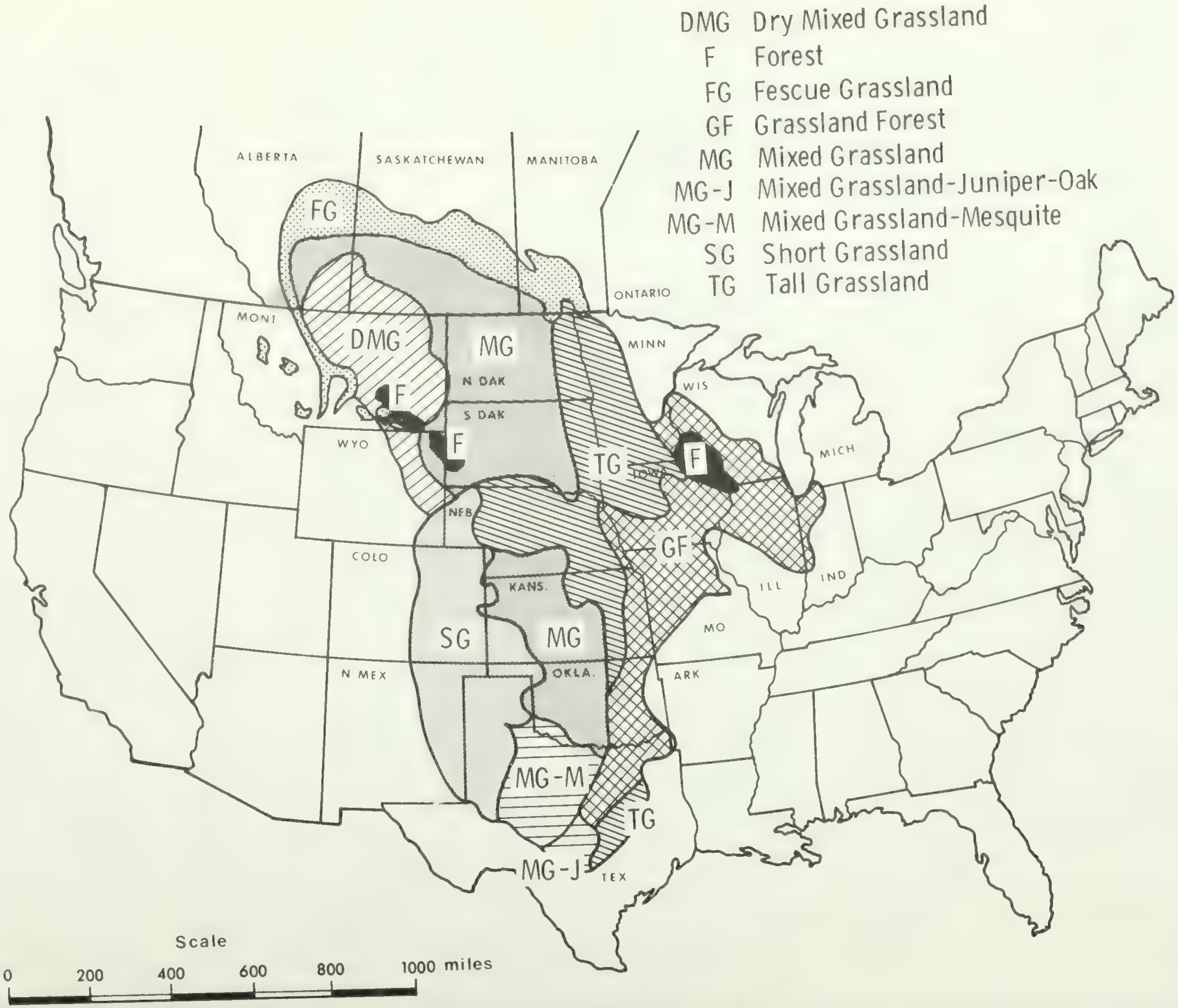

Figure 1.--Natural vegetation of Great Plains grasslands. Modified from Kuchler (1965) and Rowe (1972).

Southern Great Plains

DISTRIBUTION, CLIMATE, SOILS AND VEGETATION

The southern Great Plains includes the eastern third of New Mexico, the northern wo-thirds of Texas, and most of Oklahoma. Within the region, the shortgrass prairie High Plains) (fig. 2), lies west of the 100° meridian. Annual precipitation in the hortgrass prairie varies from 15 to 20 inches (38 to 51 cm). Except for the sandy oils in southeastern New Mexico and the Canadian River country in northern Texas and estern Oklahoma, soils are primarily clay loams, silt loams, and sandy loams. A aliche layer is frequently present at 20 to 36 inches (51 to 91 cm) in the fine-extured soils. Most of the area is tableland that is 4,000 to 6,000 ft (1 200 to 829 m) elevation (south to north) on the western edge, and slopes eastward to ,000 ft (915 m) on the edge of the Caprock in Texas. Dominant grasses are buffalo-rass (*Buchloe dactyloides*) and bluegrama (*Bouteloua gracilis*), with varying amounts f threeawns (*Aristida* sp), lovegrass (*Eragrostis* sp.), tridens (*Tridens* sp.), and dropseed (*Sporobolus cryptandrus*), sideoats grama (*Bouteloua curtipendula*), obosagrass (*Hilaria mutica*), galleta (*H. jamesii*), vine-mesquite (*Panicum obtusum*), ush muhly (*Muhlenbergia porteri*), and Arizona cottontop (*Digitaria californica*). orbs can be abundant during wet years, but they are seldom a major component of the hortgrass prairie.

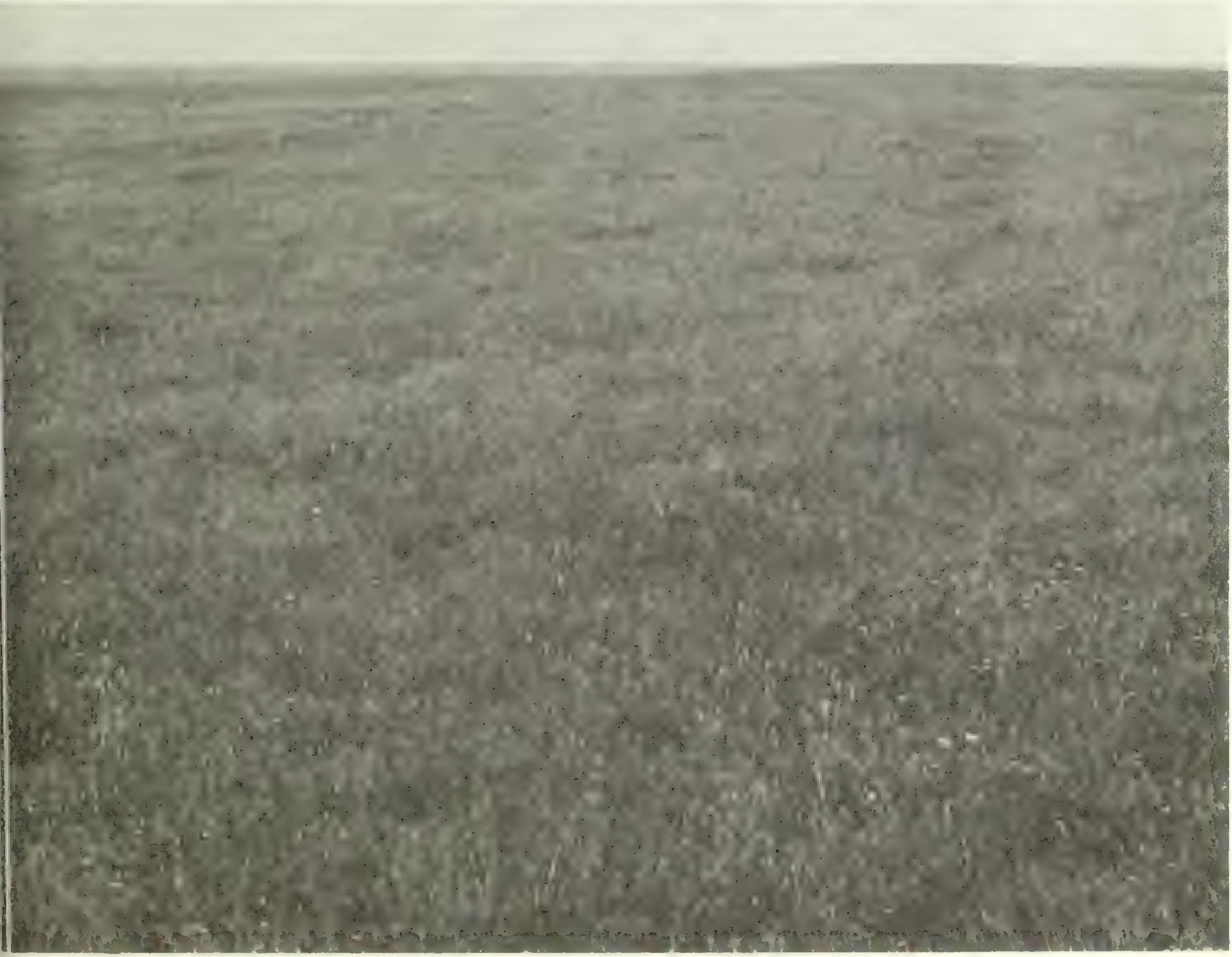

Figure 2.--Shortgrass prairie in Panhandle of northern Texas. Dominant species are blue grama and buffalograss.

Major forbs include annual broomweed (*Xanthocephalum dracunculoides*), false mesquite (*Hoffmanseggia densiflora*), western ragweed (*Ambrosia psilostachya*), horsetail conyza (*Conyza candensis*), warty euphorbia (*Euphorbia spathulata*), silverleaf nightshade (*Solanum elaeagnifolium*), manystem evax (*Evax multicaulis*), woolly plantago (*Plantago purshii*), dozedaisy (*Aphanostephus* sp.), goosefoot (*Chenopodium* sp.), croton (*Croton* sp.), summercypress (*Kochia scoparia*), and globemallow (*Sphaeralcea* sp.).

Dominant woody plants are honey mesquite, sand shinnery oak (*Quercus havardii*), sand sagebrush (*Artemisia filifolia*), perennial broomweed (*Xanthocephalum sarothrae*), yucca (*Yucca* sp.), and fourwing saltbush (*Atriplex canescens*). Cactus (*Opuntia* sp.) can also be abundant. The most prevalent species include plains pricklypear (*Opuntia polyacantha*), brownspine pricklypear (*O. phaecantha*), walkingstick cholla (*O. imbricata*), and tasajillo (*O. leptocaulis*).

East of the shortgrass plains is the mixed prairie (Rolling Plains and Edwards Plateau). It includes most of west-central Texas and western Oklahoma. Elevation drops from 3,000 ft (915 m) along the western edge to about 900 ft (274 m) along the eastern edge in central Texas and Oklahoma. Topography is undulating, with occasional breaks and rivers. The zone is about 150 miles (242 km) wide and precipitation varies from 20 inches (51 cm) on the western edge to 28 inches (71 cm) on the eastern edge. Soil textures are primarily clay loams, silt loams, and sandy loams.

Honey mesquite (fig. 3) and Ashe juniper (fig. 4) dominate the overstory in Texas, but these species are not prevalent in Oklahoma. In the Rolling Plains, honey mesquite dominates the overstory. Lotebush (*Zizyphus obtusifolia*) is an important subdominant shrub that provides cover for bobwhite quail and nesting for many songbirds (Renwald 1977; Renwald and others 1978). Other shrubs include fourwing saltbush, elbowbush (*Foresteria pubescens*), ephedra (*Ephedra* sp.), skunkbush sumac (*Rhus trilobata*), dalea (*Dalea* sp.), and acacia (*Acacia* sp.). Breaks throughout the Rolling Plains contain large amounts of redberry juniper (*Juniperus pinchoti*), which resprouts from crown buds after fire. Cactus species similar to those in the shortgrass prairie are also present throughout the Rolling Plains (fig. 5 and 6).

Dominant grasses include sideoats grama, tobosagrass, buffalograss, little bluestem (*Schizachyrium scoparium*), and the cool season grass, Texas wintergrass (*Stipa leucotricha*). Other grasses include vine-mesquite, Arizona cottontop, sand dropseed, white tridens (*Tridens albescens*), threeawn species, plains bristlegrass (*Setaria leucopila*), and green sprangletop (*Leptochloa dubia*). Many annual forbs grow during wet winters, but annual broomweed and bitterweed (*Hymenoxys odorata*) are the only forbs abundant over a wide area. Other genera include *Engelmannia, Gaillardia, Oenothera, Aphanostephus, Chenopodium, Gaura, Helianthus, Plantago, Solanum,* and *Sphaeralcea*.

In the Edwards Plateau, southeast of the Rolling Plains, Ashe juniper dominates the overstory. Other major species include interior live oak, Texas oak (*Quercus shumardii* var. *texana*), post oak (*Q. stellata*), blackjack oak (*Q. marilandica*), smoothleaf sumac (*Rhus glabra*), Mexican redbud (*Cercis canadensis* var. *mexicana*), and shin oak (*Quercus* sp.). Dominant grasses include little bluestem, sideoats grama, Texas wintergrass, tall grama (*Bouteloua pectinata*), vine-mesquite, buffalograss, and meadow dropseed (*Sporobolus asper* var. *hookeri*). Forbs are similar to those in the Rolling Plains.

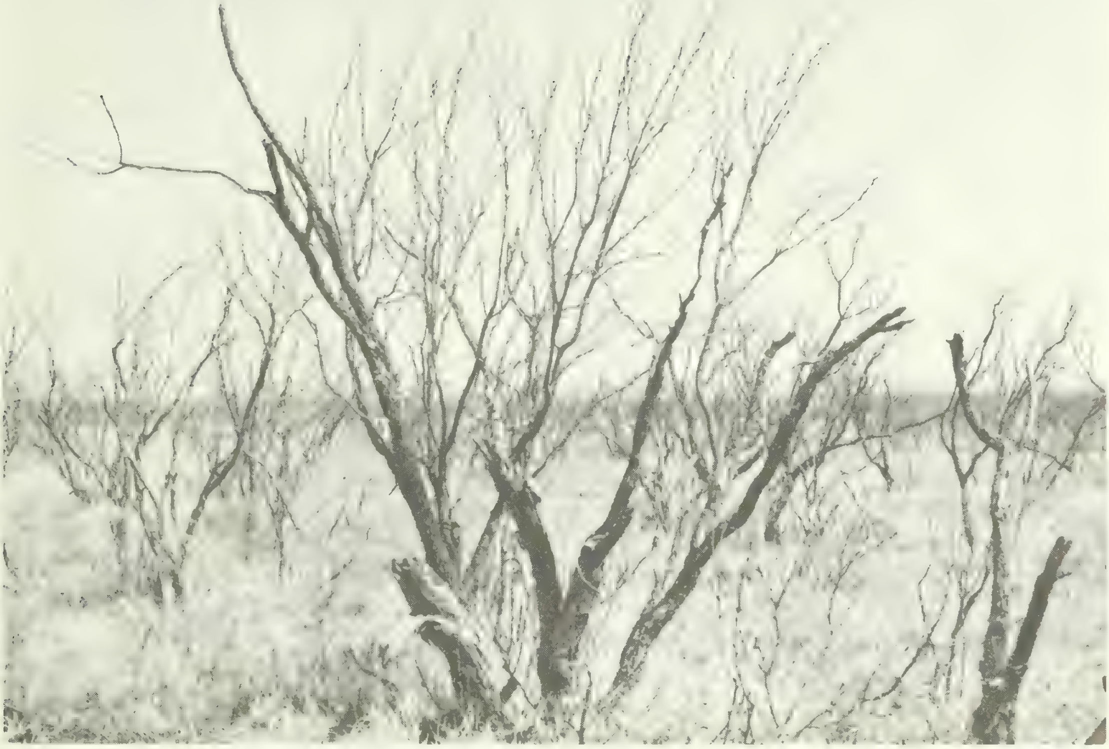

Figure 3.--A mesquite-tobosa community (dormant season) with 4,070 lb/acre (4,573 kg/ha) of fine fuel in the mixed prairie near Colorado City, Texas.

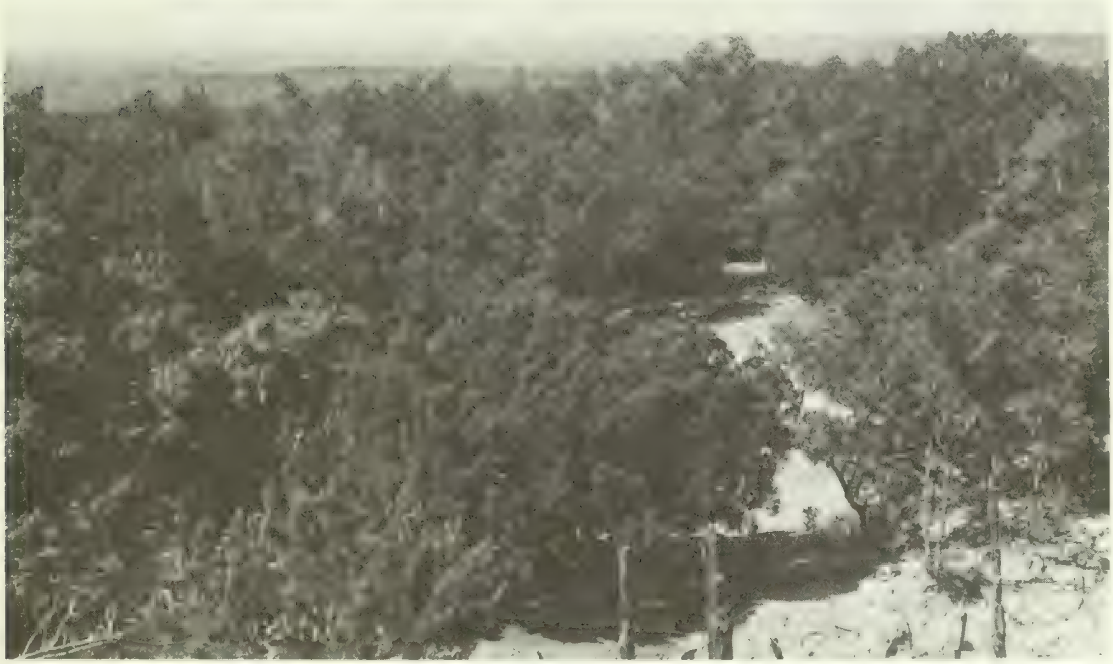

Figure 4.--A heavily grazed stand of Ashe juniper in the mixed prairie of central Texas that will need a major reclamation program to revert it back to a natural grassland. Such communities need fire every 20 years or so and good management to keep Ashe juniper out.

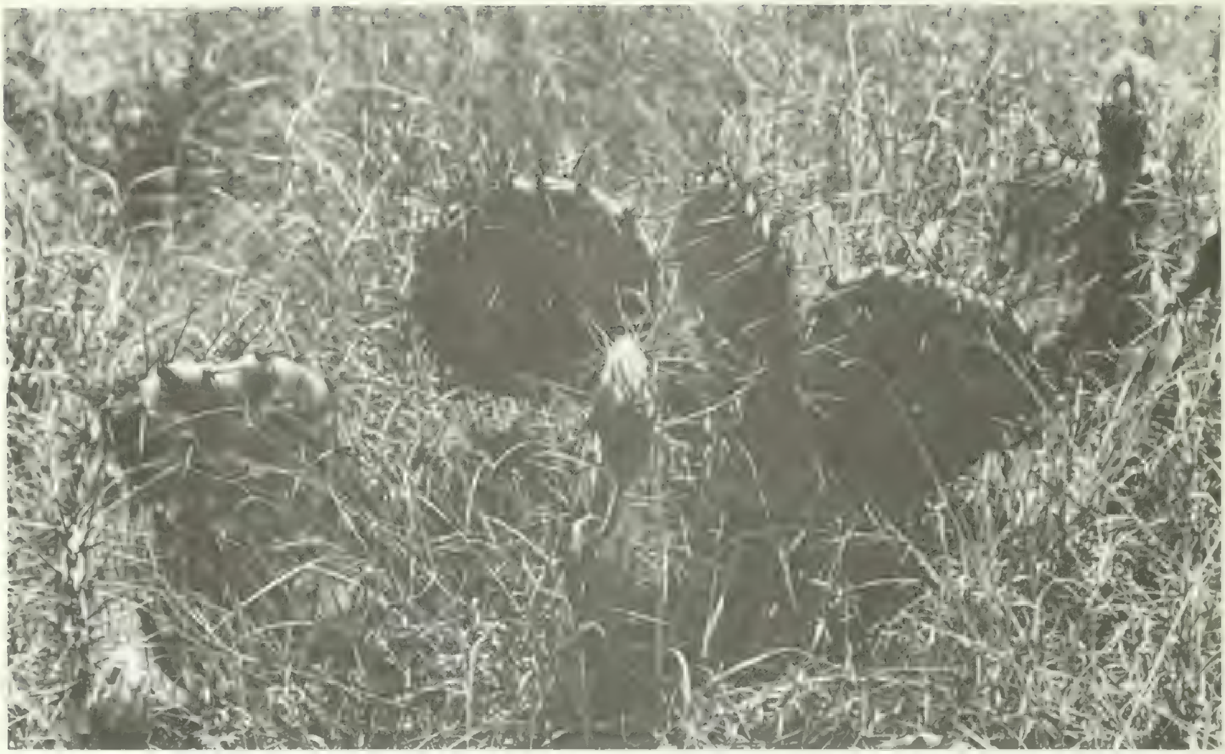

Figure 5.--Pricklypear (*Opuntia phaecantha*) can easily be killed with fire. Generally 70 to 80 percent of the plants are dead 2 to 3 years after a fire because of a fire-insect interaction.

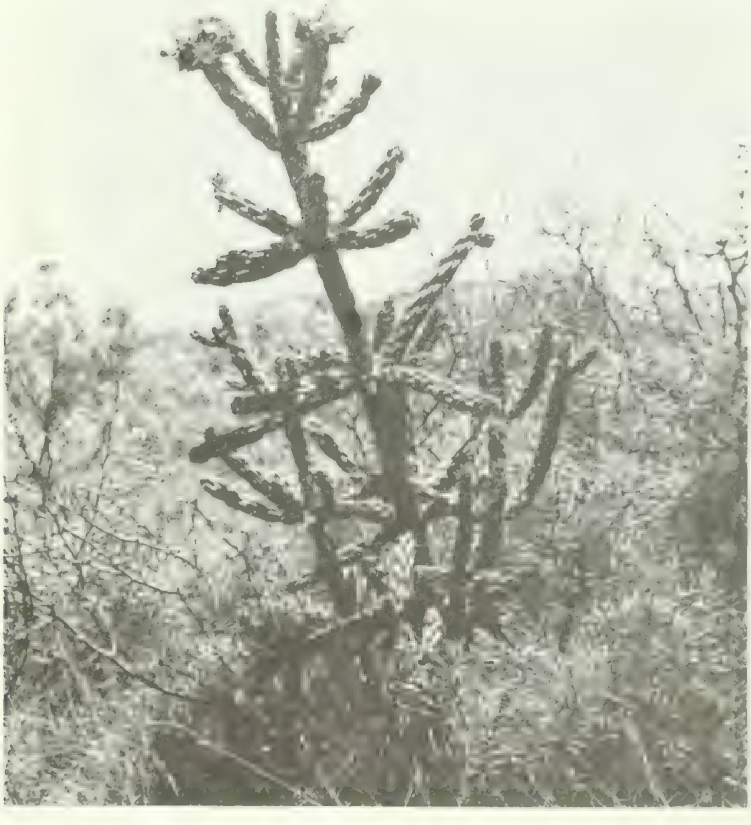

Figure 6.--Cholla are easily kille if less than 2 ft (0.61 m) tall. About 50 percent of the plants die after being burned.

The tallgrass prairie is mixed with various amounts of the "Cross Timbers" from central Texas and Oklahoma to their eastern boundaries. The Cross Timbers are dominated by post oak and blackjack oak and occur on sandy soil. Precipitation varies from 27 to 45 inches (69 to 114 cm). Deep sandy loam and silt loam soils are common in the pure grasslands. Elevation varies from 500 to 1,000 ft (152 to 305 m), sloping generally to the east. Dominant grasses are little bluestem, big bluestem (*Andropogon gerardi*), Indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*). Shrubs vary in abundance, with the important ones being smoothleaf sumac, leadplant (*Amorpha canescens*), and wild plum (*Prunus* sp.). Forbs are similar to those mentioned for tallgrass prairie of the central Great Plains.

FIRE EFFECTS - SHORTGRASS PRAIRIE

Grasses.--During dry years, most species of the shortgrass prairie are harmed by fire. Following a spring wildfire, when the soil was dry, Launchbaugh (1964) found that the recovery time for a buffalograss-blue grama community took three growing seasons. Recovery was 35, 62, and 97 percent following the first, second, and third growing seasons, respectively. Hopkins and others (1948) reported similar results in west-central Kansas. Western wheatgrass (*Agropyron smithii*) recovered more slowly--18, 27, 77 percent for the three growing seasons (Launchbaugh 1964). Following a wildfire in New Mexico when the moisture balance was more favorable, Dwyer and Pieper (1967) found that the production of blue grama was reduced only 30 percent the first year. With above-average precipitation the second year after burning, blue grama had recovered. Results from prescribed burns in Texas during years with above-normal winter and spring precipitation show that buffalograss and blue grama tolerate fire with no loss in herbage yield at the end of the first growing season (Trlica and Schuster 1969; Heirman and Wright 1973; Wright 1974b) (table 1).

Table 1.--*Yields of buffalograss and blue grama after burning during a year with above-normal precipitation (wet year) and a year with below-normal precipitation (dry year)*

Year after burn	Burned		Unburned	
	Current growth	Litter	Current growth	Litter
	lb/ha (kg/acre)			
Wet years (Texas data)[1]				
Buffalograss				
First (1968)	1,686 (1,894)	-- --	1,494 (1,679)	728 (818)
Second (1969)	2,063 (2,318)	306 (344)	1,928 (2,166)	458 (515)
Third (1970)	1,398 (1,571)	572 (1,766)	1,330 (1,494)	906 (1,018)
Blue grama				
First (1970)	1,680 (1,888)	-- --	1,429 (1,606)	2,474 (2,780)
Second (1971)	1,369 (1,538)	699 (785)	1,247 (1,401)	2,584 (2,904)
Third (1972)	2,142 (2,407)	1,750 (1,966)	1,754 (1,971)	1,932 (2,171)
Dry years (Kansas data)[2]				
Buffalograss-blue grama				
First (1959)	1,100 (1,236)	-- --	3,150 (3,539)	500 (562)
Second (1960)	1,840 (2,067)	250 (281)	3,000 (3,371)	500 (562)
Third (1961)	2,600 (2,921)	330 (371)	2,650 (2,978)	550 (618)

[1] Data from Wright (1974b).

[2] Data from Lauchbaugh (1964).

The tolerance of most grass species to fire in the shortgrass prairie, under different moisture regimes, appears to be similar to that for buffalograss and blue grama. Red threeawn (*Aristida longiseta*) and sand dropseed are usually harmed by fire (Hopkins and others 1948; Dwyer and Pieper 1967; Trlica and Schuster 1969). By contrast, Wright (1974b) found that sand dropseed tolerated fire when winter and spring precipitation were 40 percent above normal. Other species that Dwyer and Pieper (1967) found to be harmed by fire included slim-stemmed muhly (*Muhlenbergia filiculmis*), ring muhly (*M. torreyi*), wolftail (*Lycurus phleoides*), and galleta. These species were harmed by a wildfire during a year of below normal precipitation. Tumble windmillgrass (*Schedonnardus paniculatus*) was not harmed by fire (Trlica and Schuster 1969). Weeping lovegrass (*Eragrostis curvula*), an introduced species, is increased 14 percent by burning, but the greatest benefit from burning is a 53 percent increase in utilization (Klett and others 1971).

In the southern shortgrass plains, sandy lands are common among the heavy clay soils that are dominated by buffalograss and blue grama. The sandy soils are dominated by sand bluestem (*Andropogon hallii*), little bluestem, switchgrass, and sand shinnery oak. Burning generally increases production of sand bluestem and switchgrass about 300 lb/acre (337 kg/ha) and similarly decreases production of little bluestem, with a net increase in total forage of 20 percent (McIlvain and Armstrong 1968).

Forbs.--Grasses provide the major portion of prairie vegetation, but many species of forbs occur during years with above-normal precipitation. Heirman and Wright (1973) found that spring burning was temporarily detrimental to many forbs: annual broomweed, silverleaf nightshade, western ragweed, and horsetail conyza. Warty euphorbia multistem evax, and woolly plantago were not affected, and false mesquite was favored by the burn.

Total forb yields are usually reduced more by spring burns than fall burns (Hopkins and others 1948). In all cases, however, forb composition will be altered the least by burning when plants are dormant. Young, active growing forbs will be severely harmed by fire.

Shrubs.--The shortgrass prairie does not have many species of shrubs, but shrubby mesquite is abundant on native ranges in the southern mixed prairie. Mesquite has not always been a noticeably prevalent shrub on the High Plains (shortgrass prairie) of Texas. The following observations were made by Captain R. B. Marcy (1849) as he traveled with his command over the northern part of the Llano Estacado near present day Amarillo, Texas:

> When we were on the high tableland, a view presented itself as boundless as the ocean. Not a tree, shrub, or any other object, either animate or inanimate, relieved the dreary monotony of the prospect; it was a vast illimitable expanse of desert prairie--the dreaded "Llano Estacado" of New Mexico; or, in otherwords, the great Zahara of North America. It is a region almost as vast and trackless as the ocean--a land where no man, either savage or civilized permanently abides; it spreads forth into a treeless, desolate waster of uninhabited solitude, which always has been, and must continue, uninhabited forever; even the savages dare not venture to cross it except at two or three places, where they know water can be found. The only herbage upon these barren plains is a very short buffalograss, and, on account of a scarcity of water, all animals appear to shun it.

Today, honey mesquite is not only prevalent on the High Plains, but it is almost impossible to kill with fire after it is 1 ft (0.3 m) tall (Wright and others 1976a). Even the seedlings are very tolerant of fire (Fisher 1947). Honey mesquite on the High Plains has an exceptional ability to resprout, compared to mesquite in the Rolling Plains (mixed prairie). Based on fire tolerance and the very few recorded observations of honey mesquite by early explorers on the High Plains (Malin 1953; Box 1967), we believe that before European man's arrival honey mesquite maintained a low growth form and high frequency. On the High Plains, honey mesquite seems to be genetically adapted to fire because of the necessity to survive frequent fires in its past history. Thus, it is possible that the combination of fire, drought, competition from grasses, and damage from small mammals, particularly rabbits and rats, combined to maintain a low-growth form of mesquite.

On sandy loams in eastern New Mexico, northern Texas, and western Oklahoma, sand shinnery oak is abundant, while in southeastern New Mexico the sandy land is dominated by shrubby honey mesquite. Sand shinnery oak is fire tolerant. Density of its stems increases 15 percent after burning (McIlvain and Armstrong 1966); however, acorns are not formed during the year of the burn, which could reduce feed available for prairie chickens and wild turkeys.

Algerita (*Berberis trifoliata*), fourwing saltbush, winterfat (*Eurotia lanata*), and skunkbush sumac resprout vigorously after fire in New Mexico (Dwyer and Pieper 1967). Chickasaw plum (*Prunus angustifolia*) and aromatic sumac (*Rhus aromatica*) sprout vigorously after burning in the southern Great Plains (Jackson 1965). In the northern Panhandle of Texas, sand sagebrush is a sprouter and seedlings appear soon after fire (Jackson 1965).

Cacti are easily killed by fire, but 2 years may be required for mortality. Mortality of tasajillo following burning may exceed 80 percent (Bunting and others 1980). Walkingstick cholla and brownspine pricklypear are also easily killed by fire if they are less than 1 ft (0.3 m) high. Dwyer and Pieper (1967) found that chollas less than 1 ft (0.3 m) high were reduced by 50 percent after burning in New Mexico, but cacti over 1 ft (0.3 m) high were hardly damaged. Heirman and Wright (1973) reported similar data for West Texas. They attributed the high mortality of the shorter plants [1.5 to 2 ft (0.46 to 0.61 m)] to flame heights that will easily engulf the plants. Taller plants are not burned at the higher levels and survive fire in the shortgrass prairie. Chaining before burning will greatly increase mortality of tall walkingstick cholla plants (Heirman and Wright 1973).

FIRE EFFECTS - MIXED PRAIRIE

Grasses.--Most grasses of the mixed prairie tolerate fire during years with normal to above-normal precipitation, but sideoats grama and Texas wintergrass can be severely damaged. The rhizomatous form of sideoats grama is almost always reduced 40 to 50 percent by fire and requires 3 years for full recovery (Hopkins and others 1948; Wright 1974b). It tolerates fire reasonably well during exceptionally wet years, with only a 12 percent reduction in yield (Wink and Wright 1973). Texas wintergrass is severely harmed by sweeping hot fires (Dahl and Goen 1973), but increases following creeping, cool fires (Bean and others 1975). Fire will cause little bluestem to decrease as much as 58 percent during dry years (Hopkins and others 1948) or increase as much as 81 percent during wet years (Wink and Wright 1973).

Tobosagrass (fig. 3), a southern desert species, is prevalent on bottomland sites in the southern mixed prairie. It is a highly productive species (Paulsen and Ares 1962; Dwyer 1972) until it accumulates large amounts of litter (Wright 1969) that decays slowly (Weaver and Albertson 1956). Young tobosagrass leaves are palatable, but as plants mature and accumulate litter, they become coarse and unpalatable (Herbel and Nelson 1966; Wright 1972a; Heirman and Wright 1973).

Burning can greatly increase the production and palatability of tobosagrass during normal-to-wet years (Heirman and Wright 1973). During wet years after burning, tobosagrass will increase over 2,000 lb/acre (3 247 kg/ha). Over a series of dry, normal, and wet years (5 years), tobosagrass production increased an average of 1,030 lb/acre (1 157 kg/ha) the first growing season following a burn (Wright 1972a). Total production on burned areas increased over control areas for a 3-year period and then reached equilibrium during the fourth year after burning (Wright 1972a; Neuenschwander 1976). However, in southern New Mexico where annual precipitation is only 9 inches (23 cm), an increase in tobosagrass yields cannot be expected after burning (Dwyer 1972).

Since tobosagrass is such a coarse grass, it should be grazed within a few weeks after burning. If tobosagrass is rested for 3 or 4 months, as we generally recommend for most grasses, it will be so coarse that animals will not eat it. Cattle normally like to eat this grass during the spring and fall when it is growing rapidly. Heirman and Wright (1973) found that tobosagrass utilization could be increased many-fold following a burn. Normally, cattle only eat about 10 percent of the tobosagrass, but following a burn they will eat as much as 60 percent of the herbage (Heirman and Wright 1973).

Since tobosagrass and buffalograss often grow in combination and cattle will eat tobosagrass in preference to buffalograss during the spring after a fire (Heirman and Wright 1973), burning can be a means to increase the vigor of desirable grasses and in general improve the condition of the range. However, tobosagrass cannot take heavy utilization for an extended number of years (Canfield 1939). Maximum utilization of tobosagrass during any year probably should not exceed 50 percent.

As long as soil moisture is adequate, vine-mesquite, Arizona cottontop, plains bristlegrass, Texas cupgrass (*Eriochloa sericea*), the bunchgrass form of sideoats grama, and meadow dropseed thrive after fire (Box and others 1967; Wink and Wright 1973; Wright 1974b). Tall grama, a potentially susceptible bunchgrass after burning, yields as much forage as unburned controls during years with normal to above-normal precipitation (Wright 1974b).

Cool season annual grasses are severely harmed by spring burning. In the southern mixed prairie, spring fires severely reduce yields of the principal cool season grasses--little barley (*Hordeum pusillum*) and Carolina canary grass (*Phalaris caroliniana*). Care should be taken to not burn an entire field in early spring where these species occur. Otherwise, there will be very little green feed for animals during the subsequent winter months, although little barley is not a very palatable species.

Forbs.--Forbs that begin growth before the burning season are usually harmed by fire, whereas those that initiate growth after the burning season are usually not harmed by fire. In the southern mixed prairie, species usually harmed during the first growing season after burning include annual broomweed, horsetail conyza, plains dozedaisy (*Aphanostephus ramossissimus*), scarlet globemallow (*Sphaeralcea coccinea*), and bitterweed. Species common on burns include lambsquarters (*Chenopodium leptophyllum*), silverleaf nightshade, Carolina horsenettle (*Solanum carolinense*), and annual sunflower (*Helianthus annuus*). During the second growing season after burning, plains dozedaisy and redseed plantain (*Plantago rhodosperma*) reach their maximum importance value (Neuenschwander 1976).

In west-central Kansas, Hopkins and others (1948) found that spring burning severely harmed wild onion (*Allium nuttallii*) and perennial broomweed but left western ragweed and ashy goldenrod (*Solidago mollis*) unharmed.

Trees and shrubs.--The presence of honey mesquite and other shrubs in the southern mixed prairie before the arrival of Europeans has been well documented in the journals of Marcy (1849) and Michler (1850). Mesquite was present throughout the southern mixed prairie on uplands, also on bottomlands in the Rolling Plains (mixed prairie) but usually not on streambanks (Michler 1850). A map of Marcy's expedition shows vegetation marked as "mesquite timber" from Big Spring to the junction of the Clear Fork of the main Brazos River. This area was approximately 120 to 150 miles (194 to 242 km) long and 50 miles (81 km) wide. Throughout the rest of the Rolling Plains they recorded the continuous presence of mesquite, frequently as a lowgrowing shrub at the northern and southern extremities.

Fire was a part of the "mesquite timber" country. Michler (1850) gave the following description after leaving the Double Mountain Fork and the Clear Fork of the Brazos on his way to Big Spring, Texas:

> There was but little timber upon these streams upon first leaving the main fork, but the further we advanced the more we found, elm being the principal growth. The whole country was well timbered with mesquite, but most of it had been killed by prairie fires.

Evidently, this must have been a recent fire because Marcy and his command had traveled through the same country the previous year and did not mention the fire.

We have done considerable research on honey mesquite near Colorado City, Texas. It is in the "mesquite timber" country so designated by Marcy. Mesquite is moderately affected by fire, depending upon its age, number of dead basal stems with insect borer activity, weather at time of burning, and the amount of fine fuel for burning (Wright 1972a, 1972b; Wright and others 1976a). Unless very young, green mesquite trees are difficult to kill with one fire. Mesquite trees 1.5 years of age or younger were easily killed by fire when soil surface temperatures were above 500°F (260°C). At 2.5 years of age, they were severely harmed, but trees older than 3.5 years of age are fire resistant (table 2).

Table 2.--*Percentage of mortality of young mesquite trees after burning, in relation to age and maximum soil surface temperature*

Age	Soil surface temperature 93°C (200°F)	 260°C (500°F)	 427°C (800°F)	 593°C (1100°F)	Unburned
Years	*percent*				
0.5	43	91	100	100	14
1.5	60	100	100	100	0
2.5	20	40	64	72	0
3.5	8	8	8	8	4
10 (Approx.)	0	0	4	8	0

Large mesquite trees that had previously been top-killed with 2,4,5-T [(2,4,5-Trichlorophenoxy) acetic acid] were killed more easily than small trees with resprouts (Britton and Wright 1971). Insect borers had infested the larger trees after the drought of the 1950's. Fire more readily consumed the wood perforated by wood borer holes. Percentage of mortality of 1,200 trees that had resprouted after spraying in 1966 and were burned in 1969 was:

	Year				
	1969	*1970*	*1971*	*1972*	*1973*
Mortality percent	10.8	17.7	22.6	25.7	26.4

First-year mortality resulted from the ignition of dead mesquite stems, which served as a fuel source to burn down into living root crowns. To achieve this effect, winds must be in excess of 8 mi/h (13 km/h) and the relative humidity must be below 40 percent at the time of burning. After the initial fire-related kill, more trees died from the weakened condition caused by interactions among fire, drought, and biotic suppression.

Junipers are quite common throughout the prairie on rocky slopes such as escarpments, ridges, or rimrocks (Wells 1970) and on areas that have been protected from fire (Penfound 1964). In Oklahoma, Arend (1950) found that fire was the worst natural enemy of eastern redcedar (*Juniperus virginiana*), a nonsprouting species. Similarly Dalrymple (1969) and Wink and Wright (1973) have found Ashe juniper, another nonsprouting species, to be highly susceptible to fire in southern Oklahoma and central Texas. These species cannot maintain themselves in areas that burn frequently (fig. 7) because the leaves are very flammable, especially during fall months, and the bark is so thin that heat from one surface fire usually kills all trees.

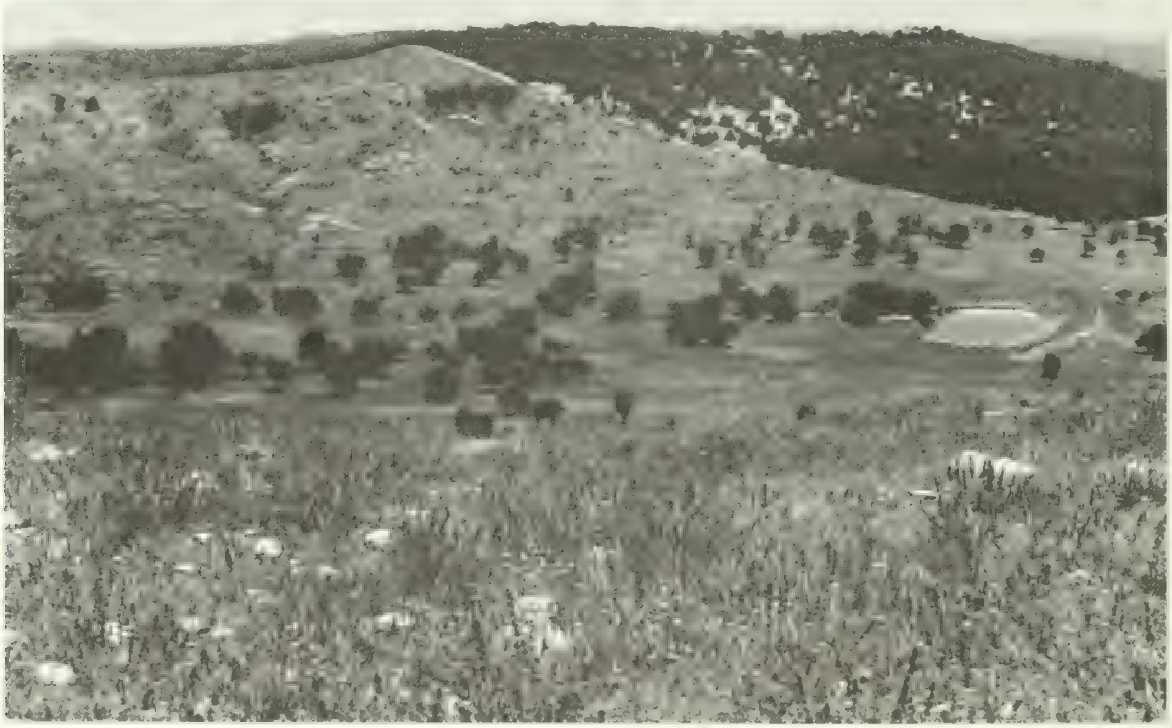

Figure 7.--Following dozing and prescribed burning, dense stands of Ashe Juniper can be reverted to grasslands. The oak trees were left for esthetic purposes. Note the untreated area in the upper right-hand corner.

With 500 to 1,000 lb/acre (562 to 1 124 kg/ha) of herbaceous fuel, Dalrymple (1969) obtained a 100 percent mortality of trees less than 2 ft (0.6 m) tall, 77 percent mortality of trees 2 to 6 ft (0.6 to 1.8 m) tall and 27 percent mortality of trees over 6 ft (1.8 m) tall, for an average mortality of 68 percent.

Where fine fuel was at least 1,100 lb/acre (1 236 kg/ha), Wink and Wright (1973) found that 99 percent of the Ashe juniper trees less than 6 ft (1.8 m) tall were killed by fire under the following weather conditions: air temperatures 75° to 85°F (24° to 29°C), relative humidity 25 to 35 percent, wind 10 to 15 mi/h (16 to 24 km/h). If fine fuel was above 2,500 lb/acre (2 890 kg/ha) all juniper trees were killed by fire. With 750 lb/acre (843 kg/ha) of fine fuel, Dwyer and Pieper (1967) reported that 70 percent of the juniper trees exposed to high temperatures of a summer wildfire had died by the following year.

Redberry juniper, a sprouting species on rough breaks in the Rolling Plains, is very difficult to kill by fire unless the trees are under 12 years of age (Smith and others 1975). However, fires reduce the sphere of influence of the trees. Very little forage grows under juniper trees. When the trees are burned, they shade less area, and grasses and forbs encroach.

Several shrub species are present in the mixed prairie of the southern Great Plains, but they are less abundant than trees. Fourwing saltbush, a palatable shrub, thrives after fire. It is a vigorous sprouter and appears to have fully recovered by 3 years after burning. Lotebush also sprouts after a fire, but requires about 6 years to recover 75 percent of its original canopy cover. Littleleaf sumac (*Rhus microphylla*) and algerita sprout following fires, but we have relatively little research data on these species in West Texas. Smoothleaf sumac and all species of oak are vigorous sprouters in Ashe juniper communities of the Edwards Plateau. Cacti are abundant in the mixed prairie and equally susceptible to fire as mentioned for the shortgrass prairie.

FIRE EFFECTS - MIXED TALLGRASS--FOREST

The Cross Timbers region occupies a sandy belt of land in east-central Texas and eastern Oklahoma. It contains post oak and blackjack oak as well as many tallgrass species. Both oak species are easily top-killed with fire but resprout vigorously. Many ranchers feel that it is no longer economical to use goats or chemicals to keep oak sprouts suppressed in bluestem pastures. Presently, there is interest in determining whether a 4-year burning rotation will be effective. However, fire research has not been done in the area and the natural role of fire is unclear.

Central Great Plains

DISTRIBUTION, CLIMATE, SOILS, AND VEGETATION

The central Great Plains extend from the foothills of the Rockies in eastern Colorado and southeastern Wyoming eastward through Kansas and Nebraska to grassland-forest communities in northwest Missouri, southern Iowa, and Illinois. Shortgrass prairie (fig. 8) lies primarily in eastern Colorado, but it also occurs in western Kansas, southeastern Wyoming, and the extreme portion of western Nebraska. Annual precipitation varies from 11 to 18 inches (28 to 46 cm). Surface soil textures are largely sand, sandy loam, loamy sand, loam, and silt loam. Elevation drops from 5,000 or 6,000 ft (1 524 to 1 829 m) along the foothills in Colorado to 3,000 ft (915 m) on the eastern edge of the shortgrass prairie in Kansas. In Nebraska the eastern elevations vary from 4,000 to 5,000 ft (1 219 to 1 524 m).

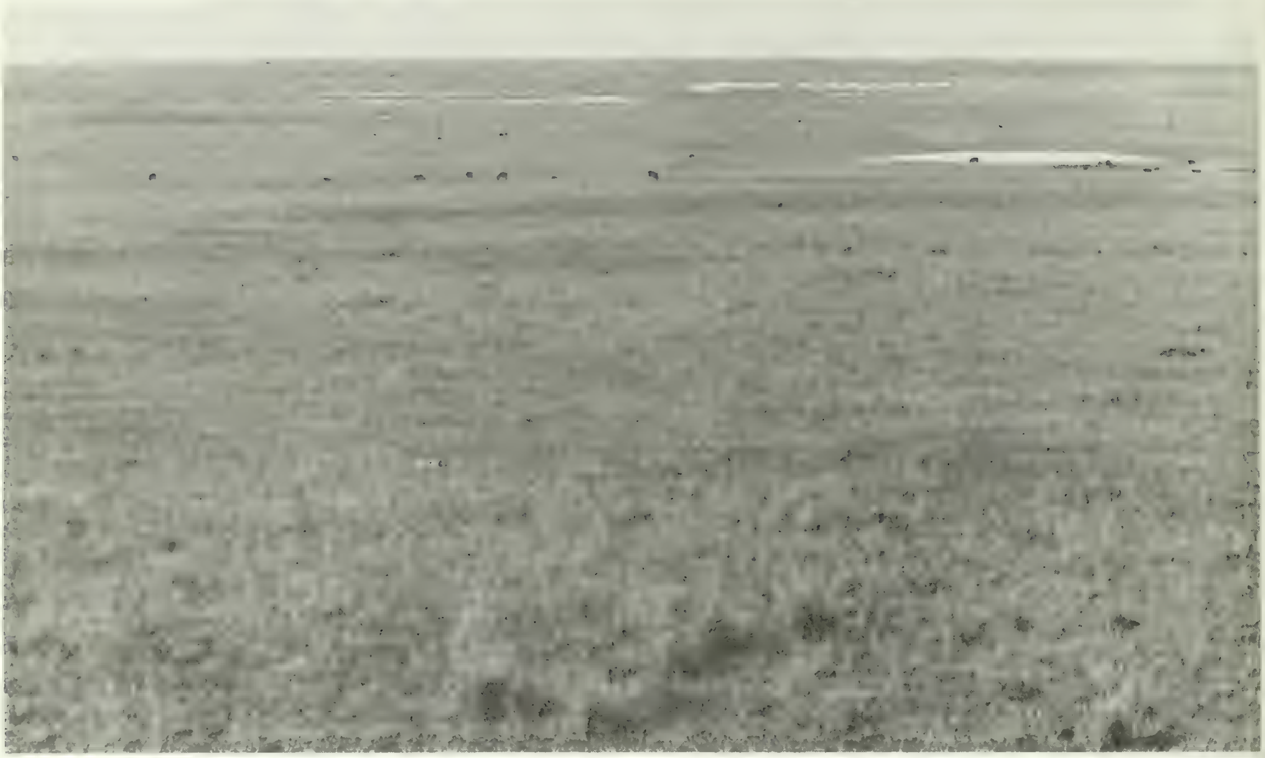

Figure 8.--Shortgrass prairie in the central Great Plains of eastern Colorado. Dominant grasses are blue grama, buffalograss, and western wheatgrass.

Buffalograss, blue grama, western wheatgrass, and scarlet globemallow are the dominants on loams and silt loams. Ranges in good-to-excellent condition will also support green needlegrass (*Stipa viridula*). Sandy-textured soils are dominated by blue grama, prairie sandreed (*Calamovilfa longifolia*), and needle-and-thread (*Stipa comata*). Other grasses and grass-like species include red threeawn, sand dropseed, and sunsedge. Well-managed ranges in eastern Colorado could also support sand bluestem, switchgrass, and Indiangrass. Dominant forbs and shrubs are western ragweed, bush morningglory (*Ipomea leptophila*), herbaceous sage (*Artemisia ludoviciana*), and fourwing saltbush.

East of the shortgrass prairie lies mixed prairie in western Nebraska and Kansas. There is tallgrass prairie, however, in the Sandhills of northwestern Nebraska. Elevation along the western edge of the mixed prairie in Kansas is 3,000 ft (915 m) but rises to as much as 5,000 ft (1 524 m) along the western edge of the Sandhills of Nebraska. Elevation starts at 1,300 ft (396 m) along the eastern edge in southern Kansas and rises to as much as 2,000 ft (610 m) in north-central Nebraska. Precipitation varies from 18 to 28 inches (46 to 71 cm) in Kansas and 18 to 25 inches (46 to 64 cm) in Nebraska. Topography varies from undulating-to-rolling ridgetops, gently sloping, and hilly with steeply sloping valley sides. Soil textures are sand, silt, loam, silt loam, silty clay loam, and clay uplands.

Dominant grasses in the mixed prairie of the central Great Plains are blue grama, ittle bluestem, sand dropseed, tall dropseed (*Sporobolus asper*), western wheatgrass, uffalograss, sideoats grama, purple threeawn (*Aristida purpurea*), needle-and-thread, unegrass (*Koeleria cristata*), and occasional sand bluestem, prairie sandreed, and witchgrass plants. Western wheatgrass and needle-and-thread become more prevalent orthward from Kansas into Nebraska. Common forbs include scarlet globemallow, western agweed, resindot skullcap (*Scutellaria resinosa*), prairie coneflower (*Ratibida columnaris*), eath aster (*Aster ericoides*), black sampson (*Echinacea angustifolia*), prairie phlox *Phlox pilosa*), prairie clover (*Petalostemum purpureum*), dotted gayfeather (*Liatris unctata*), slim-flowered scurfpea (*Psoralea tenuiflora*), Missouri goldenrod (*Solidago issouriensis*), and many others. Western ragweed and annual sunflowers are abundant n heavily grazed sites.

Tallgrass prairie in the eastern third of Nebraska, northern Iowa, and east- entral Kansas varies in elevation from 1,000 to 2,000 ft (305 to 610 m). Annual recipitation varies from as low as 23 inches (58 cm) in eastern Nebraska to as much s 35 inches (89 cm) along the eastern edge of the tallgrass prairie. The Sandhills n western Nebraska, a westward extension of the tallgrass prairie has precipitation as ow as 18 inches (46 cm) per year. With the exception of the Sandhills of Nebraska and he Flint Hills of Kansas, most of the soils are medium textured. Soils in the Flint ills are primarily Lithosols and topography is gently rolling.

Grasses of the tallgrass prairie (fig. 9) are primarily little bluestem, big luestem, switchgrass, Indiangrass, and prairie dropseed (*Sporobolus heterolepis*). ther grasses include Canada wildrye (*Elymus canadensis*), porcupine grass (*Spartina ectinata*), and eastern gamagrass (*Tripsacum dactyloides*). Additional species in the andhills of Nebraska are prairie sandreed and sand bluestem. Important shrubs include estern snowberry (*Symphoricarpos occidentalis*), inland ceanothus (*Ceanothus ovatus*), ead plant, willow (*Salix* sp.), gooseberry (*Ribes* sp.), and prairie rose (*Rosa rkansana*). A wide variety of forbs occur in tallgrass prairie (Weaver and Clements 938; Weaver and Albertson 1956). Typical genera include *Aster, Solidago, Silphium, elianthus, Astragalus, Baptisia, Callinhoe, Phlox, Sisyrinchium, Lithospermum, Viola, nemone, Tradescantia, Psoralea, Erigeron, Petalostemon, Glycyrrhiza, Echinacea, iatris, Vernonia, Coreopsis, Bidens, Kuhnia, and Carduus*. Trees of the tallgrass rairie include American elm (*Ulmus americana*), hackberry (*Celtis occidentalis*), astern redcedar, bur oak (*Quercus macrocarpa*), chinquapin oak (*Q. muhlenbergii*), astern redbud (*Cercis candensis*), bitternut hickory (*Carya cordiformis*), and oughlead dogwood (*Cornus drummondii*) (Smith and Owensby 1972; Bragg and Hulbert 1976).

Tallgrass prairie and forest combinations (fig. 10) extend eastward into eastern ansas, northwestern Missouri, southern Iowa, and Illinois. The tallgrass species are hose of the tallgrass prairie and the forest is oak-hickory (*Quercus-Carya*). Pre- ipitation increases to as much as 40 inches (102 cm) per year and elevation drops to 00 ft (152 m).

RE EFFECTS - SHORTGRASS AND MIXED GRASS PRAIRIE

Prescribed fire research has not been conducted in plant communities of the central reat Plains. Hopkins and others (1948) and Launchbaugh (1964) studied the effects of ildfire. Following dry years, Hopkins and others (1948) found that the cover and yield f big bluestem, little bluestem, hairy grama (*Bouteloua hirsuta*), sideoats grama, uffalograss, hairy sporobolus (*Sporobolus pilosus*), and blue grama were reduced by re; undesirable broadleaved plants, principally western ragweed, increased. Similarly, unchbaugh (1964) found that buffalograss, blue grama, and western wheatgrass did not lly recover after fire until the third growing season.

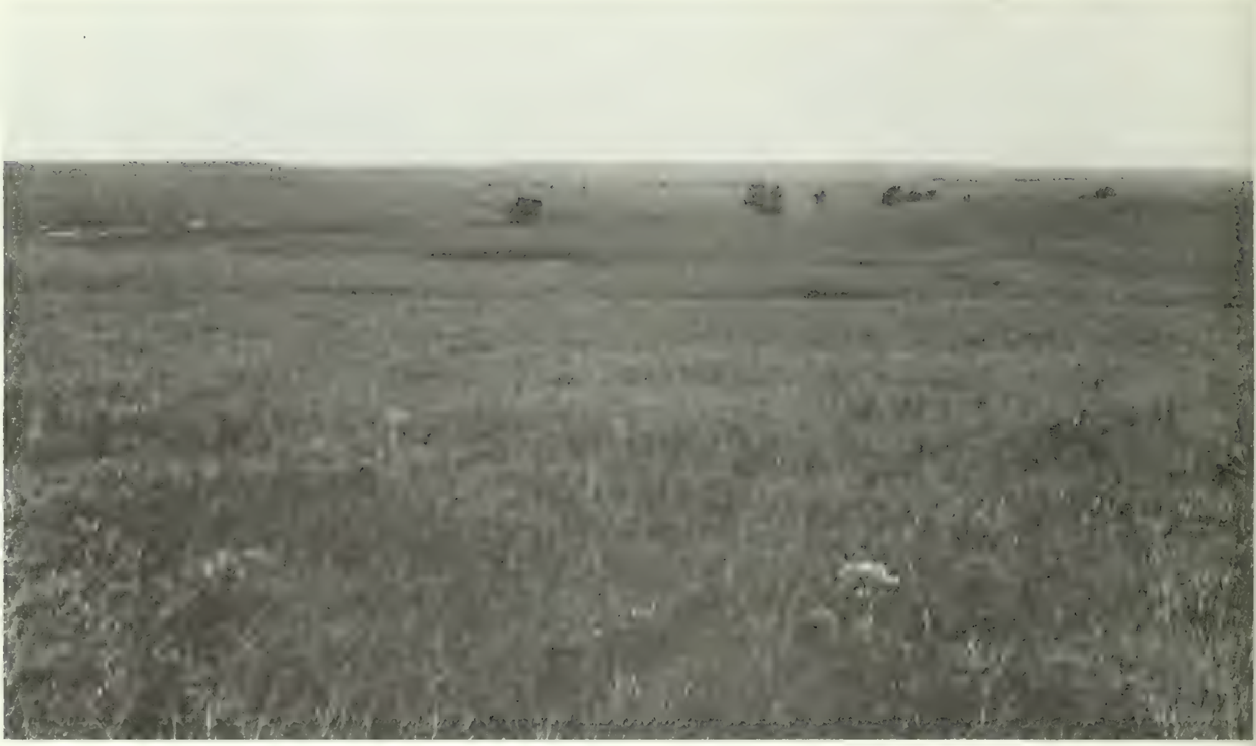

Figure 9.--Tallgrass prairie in the Flint Hills of Kansas. Rocky surface soils prevent cultivation. Dominant grasses are little bluestem, big bluestem, and Indiangrass.

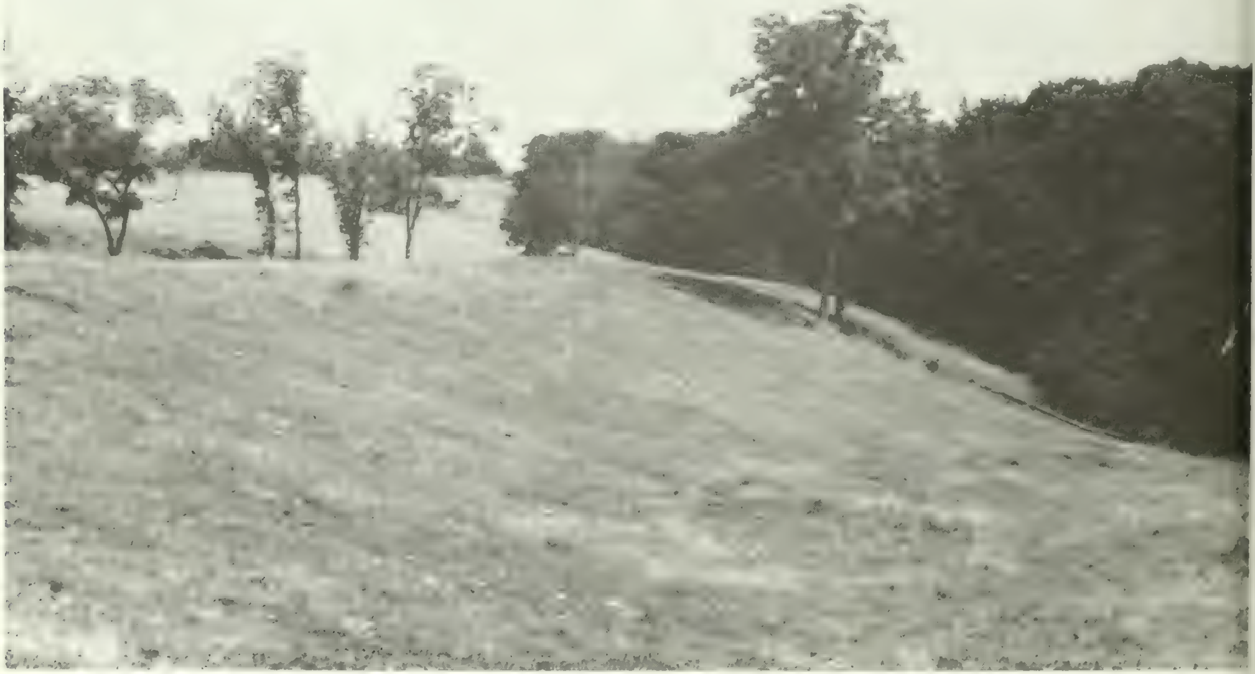

Figure 10.--Mixed grassland-forest combination in Missouri. This range is in poor condition, but would support tallgrasses if managed properly.

Based on data recorded during wet years in the southern Great Plains, there is no benefit to burning the shortgrass prairie unless there is a need to improve grazing distribution or there are unusually heavy accumulations of litter that need to be removed. Therefore, it is difficult to justify prescribed burning research in the essentially shrubless shortgrass prairie of the central Great Plains. Most of the mixed prairie is in wheat, so there is very little need for prescribed burning research in this region.

FIRE EFFECTS - TALLGRASS PRAIRIE

General comments.--Where the eastern plains have a permanently moist subsoil, Shantz and Zon (1924) suggested that the grassland had been induced by fire and drought. The environment is suited to trees when fire is absent. Work by Kucera (1960), Blan (1970), and Bragg and Hulbert (1976) support this theory. Aerial photography by Bragg and Hulbert (1976) in the Flint Hills bluestem prairie showed that on unburned pastures the combined tree and shrub cover increased 34 percent from 1937 to 1969. Tree cover alone increased 24 percent from 1856 to 1969. Invasion by trees was greatest on the deep, permeable, lowland soils. Woody plants increased only slightly on the droughty upland soils. Based on this data, Bragg and Hulbert (1976) concluded that burning had been effective in restricting woody plants to natural, presettlement levels. For Minnesota and Nebraska, however, Weaver (1954) concluded that "over most of the territory it seems probable that shrubs and woodland could not extend their areas greatly even if unhandicapped by mowing and prairie fires."

The incentive for burning in the Flint Hills of Kansas was stimulated initially by lease arrangements in the 1880's for transient steer grazing. Lessees required that the lands be burned (Kollmorgen and Simonett 1965) because the forage had higher nutritional value after burning. Livestock gains were 25 lb (11.3 kg)/steer higher on late spring burns than on adjacent unburned pastures (Smith and Owensby 1972) and growth began 7 to 10 days earlier on burned plots (Kucera and Ehrenreich 1962). Penfound and Kelting (1950) demonstrated that cattle will eat more litte bluestem on burned rangeland.

Grasses.--The effect of fire on grasses depends on the site, the amount of soil moisture, and the frequency of burning. However, there is reasonably good agreement among many authors about the effect of fire on grasses in the tallgrass prairie. Big bluestem almost always increases after burning (Robocker and Miller 1955; Kucera and Ehrenreich 1962; McMurphy and Anderson 1965; Hulbert 1969; Anderson and others 1970). Hadley and Kieckhefer (1963) noted a 275 percent increase in big bluestem 1 year after burning in Illinois, which is indicative of a decadent plant community before it is burned. Likewise Indiangrass increases after burning (Dix and Butler 1954; Robocker and Miller 1955; Kucera and Ehrenreich 1962; Hadley and Kieckhefer 1963; Anderson and others 1970).

Switchgrass has not been studied as intensively as the previous two species. However, Robocker and Miller (1955) found that it increased after burning. In a study by Anderson and others (1970), there was relatively little switchgrass in the plots and no change was detected. In a study where mulching was applied to plots, the yields of switchgrass decreased with increased mulching (Weaver and Rowland 1952).

Little bluestem also increases after single burns in the true prairie (Hensel 1923; Aldous 1934; Penfound and Kelting 1950; Dix and Butler 1954; Robocker and Miller 1955; Kucera and Ehrenreich 1962). Anderson and others (1970) did not find any change in production of little bluestem after 8 years of consecutive annual burning, provided the burns were conducted in late spring (May 1). Early spring (March 20) burns reduced yields as much as 25 percent (McMurphy and Anderson 1965; Owensby and Anderson 1967). Soil moisture has to be considerably below normal in this rainfall zone for fire to harm little bluestem (Box and White 1969).

Sideoats grama generally does not change in yield after burning (Hensel 1923; Robocker and Miller 1955; Anderson and others 1970; Smith and Owensby 1972). Other grasses that increase following early spring or winter burning include prairie junegrass (McMurphy and Anderson 1965), sand dropseed (Hensel 1923), blue grama, and hairy grama (Anderson and others 1970). Buffalograss was unchanged after 17 consecutive annual burns (Anderson and others 1970).

Cool-season grasses, particularly the introduced species, are severely harmed by spring burning. Many authors (Hensel 1923; Ehrenreich 1959; Hadley and Kieckhefer 1963; Old 1969) have reported that Kentucky bluegrass (*Poa pratensis*) decreased 80 percent or more following a spring burn. Curtis and Partch (1948) found that Canada bluegrass (*Poa compressa*) and Kentucky bluegrass were severely damaged by spring burning. Similarly, Canada wildrye and Virginia wildrye (*Elymus virginica*) (Robocker and Miller 1955), Japanese brome (*Bromus japonicus*) (McMurphy and Anderson 1965), and smooth brome (*B. inermis*) (Old 1969) are all damaged by fire. Smooth brome and similar species which begin growth about mid-May are only inhibited by burning, whereas early growing species such as Kentucky bluegrass are almost eliminated by burning (Old 1969). Fall witchgrass (*Leptoloma cognatum*) is favored by spring fires (Penfound 1964).

Kucera (1970) proposed a 3-year burning interval to maintain tallgrass dominance, as well as to retain the species diversity typical of the native prairie community.

Forbs.--Late spring burning reduces all forbs (McMurphy and Anderson 1965), although the composition of forbs is changed relatively little (Anderson 1965). Major forbs that are harmed by fire include *Petalostemum* species (Hadley 1970), heath aster and *Solidago* species (Kucera and Koelling 1964). Plains wildindigo (*Babtisia leucophilia* is favored by fire (Anderson 1965).

Wolfe (1972) studied the effects of a spring wildfire on a prairie sandreed-bluestem association in the Nebraska Sandhills. Herbage growth was reduced as much as 45 percent. Most of the decreaser forbs increased after fire while the increaser forbs declined. Forbs increasing after burning included prairie sunflower (*Helianthus petiolaris*), dotted gayfeather, Missouri goldenrod, false boneset (*Kuhnia eupatorioides*), and silky prairieclover (*Petalostemum villosum*). Those that decreased were pepperweed (*Lepedium* sp.), Virginia dayflower (*Commelina virginica*), woolly plantain, goosefoot, prairie coneflower, pigweed (*Amaranthus* sp.), and puccoon (*Lithospermum ruderale*). Western ragweed and Missouri spurge (*Euphorbia missurica*) remained unchanged.

Shrubs and trees.--There are relatively few species of shrubs in the tallgrass prairie. The shrubs favored by fire include smoothleaf sumac, lead plant (Anderson and others 1970), and western snowberry (*Symphoricarpos occidentalis*) (Pelton 1953). Coralberry (*Symphoricarpos orbiculatus*) is slightly harmed by annual spring burning, but will increase dramatically if protected from fire (McMurphy and Anderson 1965).

Eastern redcedar and western snowberry will invade a protected prairie (Penfound 1964). American elm seedlings establish early after a burn (McMurphy and Anderson 1965), but a later fire will remove the seedlings.

Seed yields.--Several articles (Burton 1944; Curtis and Partch 1950; Kucera and Ehrenreich 1962; Old 1969) have shown that herbage removal or burning increases flower stalk production. Burton (1944) reported an increase in seed yield in burned, grazed, or mowed prairie compared with ungrazed, unburned areas. Curtis and Partch (1950) working in Wisconsin reported a 6-fold increase in flowering on clearcut sites when compared to unburned areas. The increase was equivalent to that recorded on burned areas. Kucera and Ehrenreich (1962) also found that flower stalks were more numerous on burned areas. The main species affected were big bluestem, little bluestem, and Indiangrass. Quadrat counts in 1960 showed percentage increases attributable to burning of 270, 1,200, and 400 respectively.

A detailed study of the effect of litter and burning on flower stalk production was conducted by Old (1969). Cutting and raking increased the number of flower stalks for 2 years. Burning caused a greater increase in flowering, however, than did cutting (table 3). Seed yields increased because of litter removal, the removal of competing cool season plants, and increased nitrification. The increased soil temperatures after fire stimulated nitrification. The addition of ash had no effect, but the addition of 200 lb/acre (225 kg/ha) of nitrogen fertilizer increased seed yield more than burning.

Table 3.--*The effect of various herbage removal treatments on flowering in the tallgrass prairie*[1]

Treatment	Number of flower stalks	
	First year	Second year
Burning	102	74
Cut and raked	66	63
Cut and left	29	52
Undisturbed	11	34

[1] Data from Old (1969).

Litter.--Prairie closed to both grazing and fire soon begins to deteriorate (Anderson and others 1970). Accumulation of mulch depresses herbage yield and reduces the number of plant species (Weaver and Tomanek 1951; Ehrenreich 1959). Most of the decreases are associated with lower soil temperatures (Peet and others 1975).

Reduced herbage yield associated with increased litter is due in part to the amount of ammonium nitrogen. Rice and Pancholy (1973) found that the amount of ammonium nitrogen was lowest in the first successional stage, intermediate in the intermediate successional stage, and highest in the climax. The amount of nitrate nitrogen was highest in the first successional stage, intermediate in the intermediate successional stage, and lowest in the climax. The data indicate that the nitrifiers are inhibited in the climax stage so that ammonium nitrogen is not oxidized to nitrate as readily in the climax as in earlier successional stages.

Northern Great Plains

DISTRIBUTION, CLIMATE, SOILS AND VEGETATION

The northern Great Plains include the eastern two-thirds of Montana, eastern third of Wyoming, North Dakota, South Dakota, and the western edge of Minnesota. A large part of Minnesota, however, is a mixture of grassland and forest communities. This region extends 250 miles (403 km) into southeastern Alberta, southern Saskatchewan, and the southwestern tip of Manitoba (Moss 1955; Rowe 1972). The plant associations include ixed prairie, tallgrass prairie, fescue prairie, and aspen parkland. The shortgrass ssociation does not occur in the northern Great Plains. The mixed prairie includes astern Montana, eastern Wyoming, all but the eastern edges of North Dakota and South akota, as well as the southeastern portion of Alberta and southern Saskatchewan.

Precipitation varies from 10 to 24 inches (25 to 61 cm), with the driest areas located on the western edge of the mixed prairie. Soil textures are primarily sand, sandy loam, silt loam, silty clay loam, and loam. Most soils have developed from glacial till north of the 48th parallel. The last continental ice sheet left the region about 12,000 years ago. Elevation varies from 1,300 to 4,000 ft (396 to 1 219 m). The highest elevations occur in eastern Wyoming and southeastern Montana. From this high, rolling topography, elevation drops to 3,000 ft (915 m) in northern Montana and southern Alberta and then to 1,300 ft (396 m) in the eastern parts of the northern Great Plains. Topography in northern Montana and the central Dakotas is level to gently rolling, with abrupt breaks in many areas.

Annual precipitation averages 10 to 12 inches (25 to 30 cm) in the most arid parts of eastern Wyoming, and Montana, southeastern Alberta, and southwestern Saskatchewan (fig. 11). The grasses and sedges are mainly blue grama, needle-and-thread, green needlegrass, western wheatgrass, thickspike wheatgrass (*Agropyron dasystachyum*), threadleaf sedge (*Carex filifolia*), Sandberg's bluegrass (*Poa secunda*), plains muhly (*Muhlenbergia cuspidata*), little bluestem, and junegrass. Forbs are not very abundant, but pussytoes (*Antennaria* sp.), moss phlox (*Phlox hoodii*), little club moss (*Selaginella densa*), scarlet globemallow, black sampson, silverleaf scurfpea (*Psoralea argophylla*), prairie crocus (*Anemone patens* var. *wolfgangiana*), Missouri goldenrod, and others are representative species. Shrubs are predominantly fringed sage (*Artemisia frigida*), silver sage (*A. cana*), Nuttall saltbush (*Atriplex nuttallii*), winterfat, and plains pricklypear.

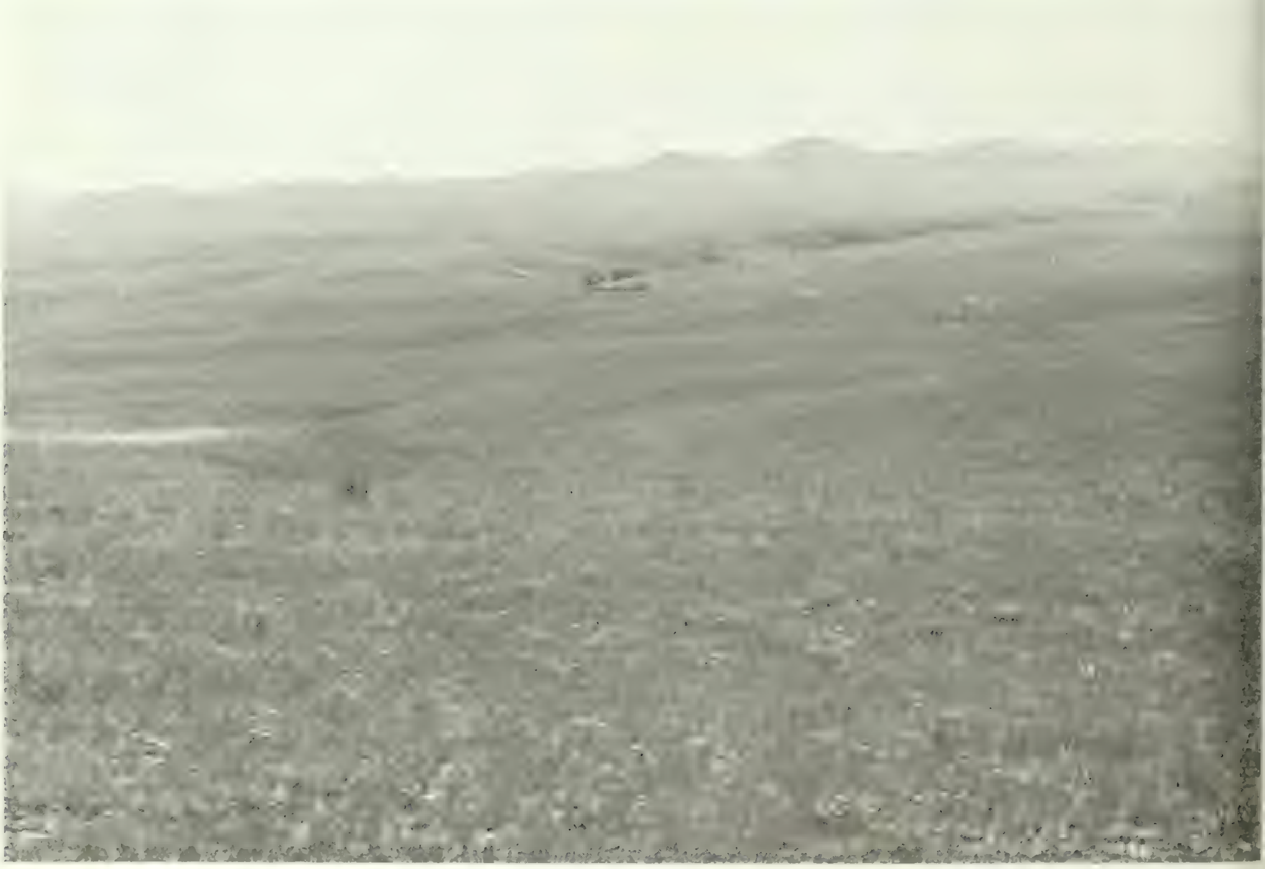

Figure 11.--Semi-arid mixed prairie (dry mixed prairie) in eastern Wyoming. Dominant species are blue grama, western wheatgrass, and needle-and-thread.

The more mesic portions of the mixed prairie (fig. 12) average 13 to 18 inches (33 to 46 cm) annual precipitation. This section occupies an arc to the north and east of the more arid areas, occurring in Alberta, Saskatchewan, North Dakota, and South Dakota. Many grass species of the arid section occur in the mesic mixed prairie along with other species. Western porcupine grass (*Stipa spartea* var. *curtiseta*) and thickspike wheatgrass are usually codominants in the Canadian sections (Coupland 1950). In North Dakota these same species are present with increasing amounts of needle-and-thread, little bluestem, junegrass, blue grama, green needlegrass, and prairie sandreed. In South Dakota, the dominant grasses are little bluestem, big bluestem, needle-and-thread, gum needlegrass, junegrass, blue grama, and western wheatgrass as well as numerous sedges. Kentucky bluegrass and smooth bromegrass, cool-season exotics, have invaded much of the northern mixed prairie in the absence of fire (Kirsch and Kruse 1972).

A variety of forbs (about 25 percent total yield) normally occur in the mixed prairie, but major species include locoweed (*Astragalus* and *Oxytropis* sp.), heath aster, aromatic aster (*Aster oblongifolius*), wild onion, American vetch (*Vicia americana*), Missouri goldenrod, woolly plantain, penstemon (*Penstemon* sp.), slim-flowered scurfpea, hairy golden-aster (*Chrysopsis villosa*), moss phlox, little club moss, wild lettuce (*Lactuca pulchella*), western yarrow (*Achillea millefolium*), plains erysimum (*Eyrsimum capitatum*), scarlet gaura (*Gaura coccinea*), white milkwort (*Polygala alba*), annual sunflower, herbaceous sage, and dotted gayfeather. Dominant invaders include summer cypress, yellow sweetclover (*Melilotus officinalis*), gumweed (*Grindelia squarrosa*), and foxtail barley (*Hordeum jubatum*), A number of shrubs are present, which include fringed sage, western snowberry, russet buffalograss (*Sheperdia canadensis*), silverberry (*Elaeagnus commutata*) rose, plains pricklypear, perennial broomweed, Nuttall saltbush, fourwing saltbush, lead plant, willow, and wild plum.

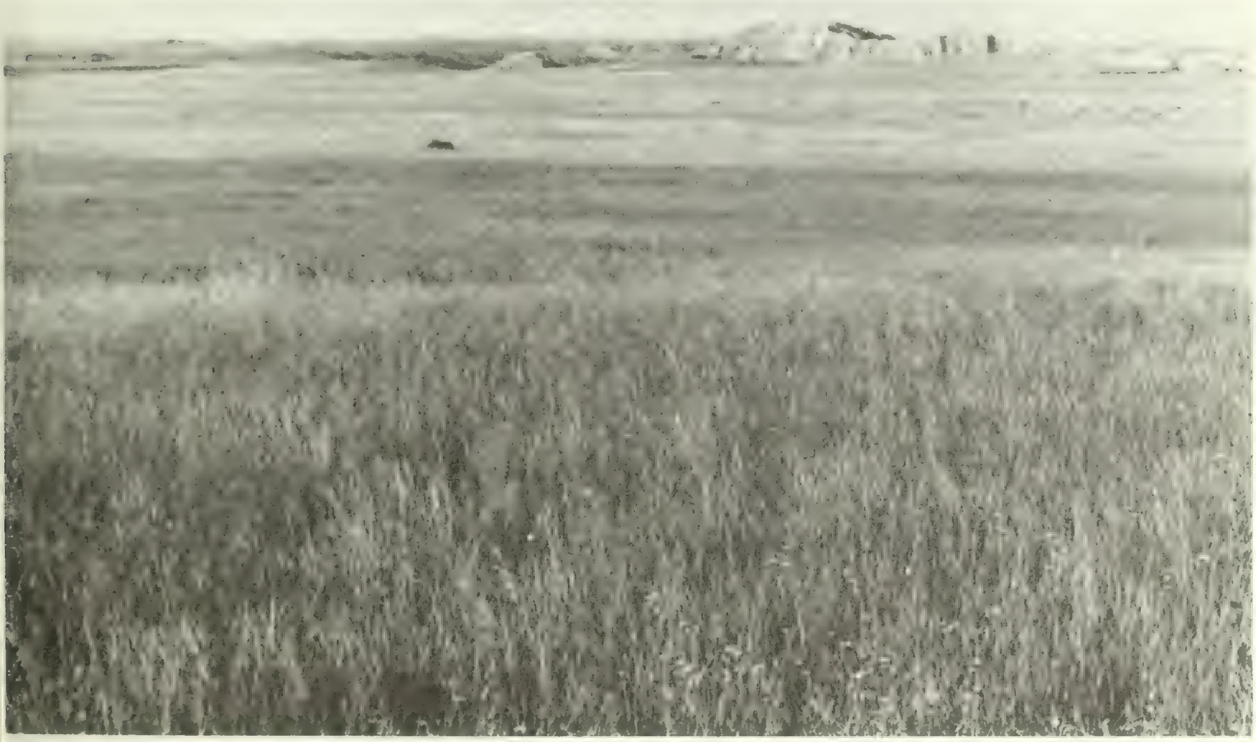

Figure 12.--Mesic mixed prairie in east-central North Dakota. Dominant grasses are thickspike wheatgrass, western wheatgrass, junegrass, green needlegrass, western porcupine grass, Canada wildrye, sedges, and little bluestem. Fire can be used in this vegetation to control introduced cool-season grasses such as Kentucky bluegrass and smooth bromegrass.

The tallgrass prairie region, which is mostly under cultivation (fig. 13), occupies the eastern edge of North Dakota and South Dakota, the western edge of Minnesota, and the southwestern corner of Manitoba. Surface soil textures are primarily loam, silt loam, and silty clay loam. Elevation varies from 800 to 1,800 ft (244 to 549 m), and topography varies from a level to gently rolling glacial plain. Precipitation varies from 18 inches (46 m) in southwestern Manitoba to 30 inches (76 cm) in south-central Minnesota. Most tallgrasses on native lands are similar to those in the tallgrass prairie of the central Great Plains. However, cool-season grasses such as porcupine grass (*Stipa spartea*), bearded wheatgrass (*Agropyron subsecundum*), quackgrass (*A. repens*), slender wheatgrass (*A. trachycalum*), smooth bromegrass, and Kentucky bluegrass, are most abundant as codominants with the bluestems, switchgrass, prairie cordgrass, and Indiangrass. The shrubs, silverberry, and fringed sage occur in addition to western snowberry, prairie rose, and smoothleaf sumac. Forbs are very similar to those mentioned for tallgrass prairie in the central Great Plains.

Fescue prairie occupies the eastern foothills of the Rocky Mountains in northwestern Montana and southwestern Alberta. It also occurs in the aspen parkland of central ALberta and Saskatchewan (fig. 14), extending eastward to southwestern Manitoba. Throughout the mixed prairie in Canada, patches of fescue grassland occur on north-facing slopes and at higher elevations where the precipitation is most effective (least evaporation). Annual precipitation ranges from 14 to 18 inches (36 to 46 cm) in the aspen parkland to 15 to 24 inches (38 to 61 cm) in the foothills. Soil textures are primarily sandy loam, and loam. Most of the area has been glaciated. Fescue grasslands occur at elevations as high as 7,500 ft (2 287 m) in the Rocky Mountains in Canada. Most foothill fescue grasslands are at 3,500 to 6,000 ft (1 067 to 1 829 m). Fescue grasslands in the parklands are at 2,000 ft (610 m) in central Alberta, descending gradually to 1,200 ft (366 m) in southeastern Manitoba. The greatest topographic relief is in the Rocky Mountain foothills. Plains topography ranges from level to sharply rolling.

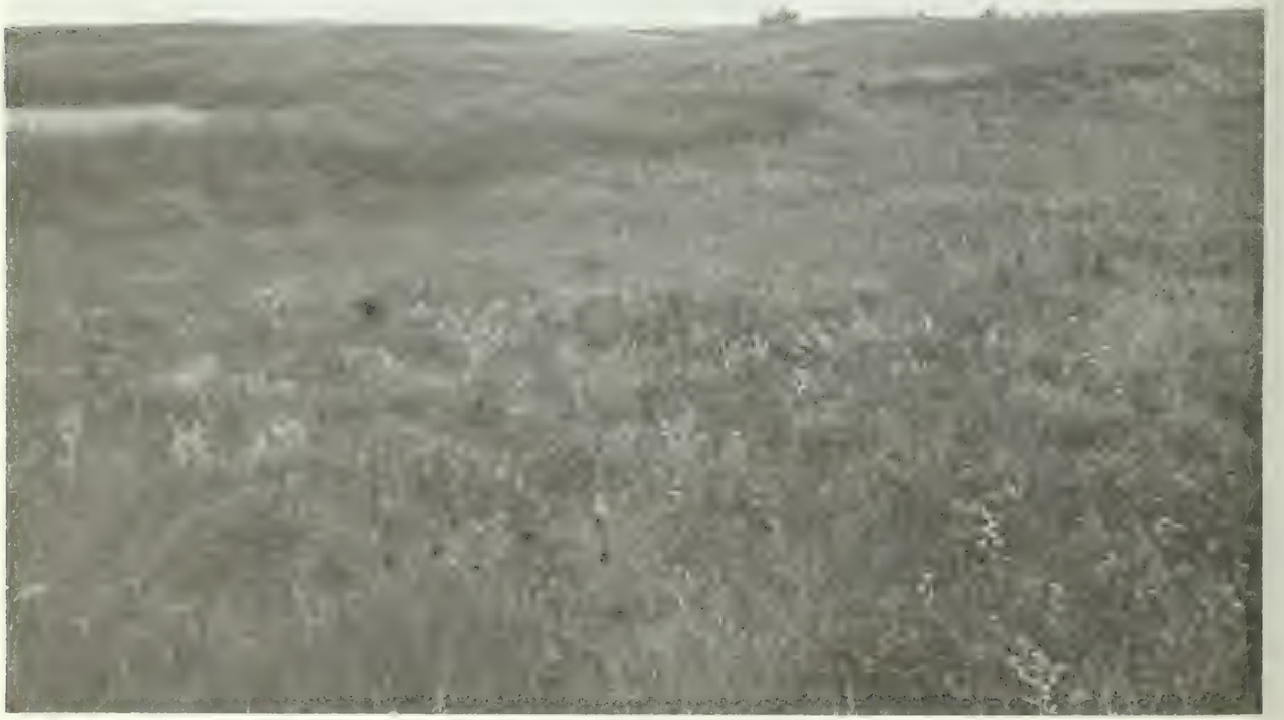

Figure 13.--Tallgrass prairie in eastern North Dakota, with marsh area.

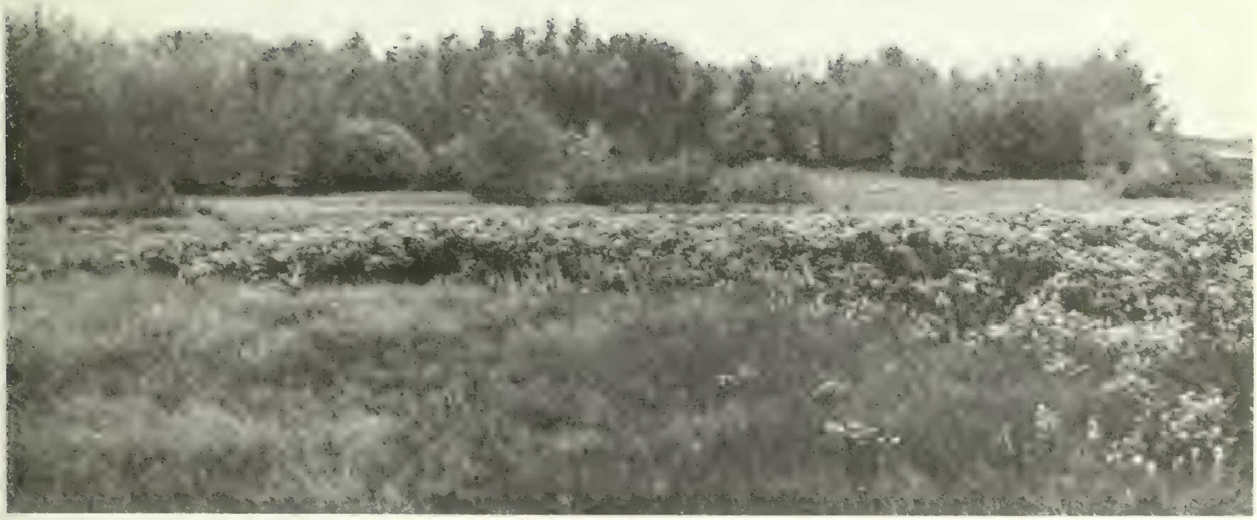

Figure 14.--Fescue prairie in the aspen parkland of Edmonton, Alberta. Dominant grass is rough fescue with some western porcupine grass.

The fescue prairie can be divided into two sections: a foothills and mountain flora, and a plains or aspen parkland flora. Mountain glaciers left a number of areas uncovered, providing a refuge for the flora. The foothills fescue prairie is a species-rich flora. Continental glaciers apparently eliminated some species from the plains region. About 50 species present in the fescue prairie of the foothills are absent from the fescue prairie in central Alberta and Saskatchewan.

Grasses in the foothills region include the dominant, rough fescue (*Festuca scabrella*), Parry's oatgrass (*Danthonia parryi*), Idaho fescue (*Festuca idahoensis*), bluebunch wheatgrass (*Agropyron spicatum*), intermediate oatgrass (*Danthonia intermedia*), slender wheatgrass, and Hooker's oatgrass (*Helictotrichon hookeri*). Timothy (*Phleum pratense*), Kentucky bluegrass, and smooth bromegrass are now common exotic species in valley bottoms and on lower slopes. In foothills, rough fescue is a 3-ft (0.9-m) tall, 10- to 20-inch (25- to 51-cm) diameter bunchgrass (Moss and Campbell 1947), but in parklands is an 18-inch (46-cm) tall, 1- to 2-inch (2.5- to 5.1-cm) diameter bunchgrass having short rhizomes. Western porcupine grass is frequently codominant with rough fescue in central Alberta and Saskatchewan. Parry's oatgrass, Idaho fescue, and bluebunch wheatgrass are absent. Several grasses from the mixed prairie frequently occur. They include thickspike wheatgrass, blue grama, needle-and-thread, and prairie sandreed. Cool-season grasses from the Boreal forest that occur throughout the fescue prairie on more mesic sites include narrow reedgrass (*Calamagrostis neglecta*), northern reedgrass (*C. inexpansa*), tufted hair grass (*Deschampsia caespitosa*), hairy brome (*Bromus ciliatus*), sweetgrass (*Hierochloe odorata*), and purple oatgrass (*Schizachne purpurascens*). The common sedges are blunt sedge (*Carex obtusata*), sun sedge, Pennsylvania sedge, and low sedge.

Foothill grasslands are rich in forbs, including yarrow, pussytoes, herbaceous sage, purple aster (*Aster laevis*), milk vetch, balsamroot (*Balsamorhiza sagitata*), sticky geranium (*Geranium viscosissimum*), hedysarum (*Hedysarum americanum*), dotted gayfeather, puccoon, lupine, vetch, and death camas (*Zygadenus gramineus*). Forbs are less important in fescue grasslands of the parklands and include yarrow, pussytoes, herbaceous sage, purple aster, milk vetch, Missouri goldenrod, buffalo bean, prairie crocus, moss phlox, American vetch, northern bedstraw (*Galium boreale*), and wild strawberry (*Fragaria virginiana*).

Shrubby cinquefoil (*Potentilla fruticosa*) increases with grazing intensity in fescue grasslands of the foothills, but it does not extend into the plains northeast of Calgary. Other shrubs common throughout the fescue grasslands include silverberry, western snowberry, willow, roses, fringed sage, and serviceberry. The trees, aspen (*Populus tremuloides*) and balsam poplar (*P. balsamifera*), are invading the more mesic sites throughout the fescue grasslands. Willows and conifers [white spruce (*Picea glauca*), Douglas-fir (*Pseudotsuga menziesii*)] are also invading many grasslands in the Rocky Mountain foothills because of the cessation of wildfires. If trees remain, the soils are expected to change from the productive black chernozems to less productive, less fertile, grey luvisols (Dormaar and Lutwick 1966).

FIRE EFFECTS - SEMIARID MIXED PRAIRIE [Precipitation less than 15 inches (38 cm) in the United States and less than 13 inches (33 cm) in Canada]

Prescribed burning has been studied only in the arid portion of the mixed prairie (Clarke and others 1943). The study evaluated effects of spring and fall burning of *Stipa-Bouteloua* and *Agropyron smithii-A. dasytachyum* ranges in southeastern Alberta. Coupland (1973) and DeJong and MacDonald (1975) have studied the effect of an August wildfire on equivalent *Agropyron* sites in southwestern Saskatchewan. All fires reduced herbage yield. Coupland (1973) found that 1 year after the burn, production of western and thickspike wheatgrass was reduced 19 percent, junegrass was reduced 63 percent, low sedge was increased 36 percent, and green needlegrass was increased 45 percent. Total grass production was reduced 13 percent. At the end of the three growing seasons, current growth was 69 to 73 percent of unburned areas. DeJong and MacDonald (1975) also studied the effects that an August wildfire had on soil moisture regime. Major effects of burning were reduction in soil moisture recharge the first winter after the fire and lower water use the growing season following burning. Less efficient moisture storage on the burned site was probably due to snow blowing off the area. By the second winter, soil moisture recharge was the same on burned and unburned grasslands. However, soil moisture continued to be lower under burned grassland throughout the first and second growing seasons after fire. Apparently, the wildfire reduced soil moisture infiltration rate on the clay soils for at least the first 2 years.

Increased water stress on plants of the burned site was measured by Redmann (1978). Both water potential and osmotic potential of leaves of thickspike wheatgrass and junegrass were lower on the burned areas. The primary effect of burning appeared to be an alteration of micro-climate, resulting in the development of an unfavorable plant and soil water status. Duration of this detrimental effect is not known. However, annual herbage production was still 28 percent less on burned than on unburned plots by the third growing season after the wildfire.

Clarke and others (1943) found that prescribed burning in the spring reduced yield 50 percent the first year and 15 percent the second year, with full recovery the third year. Fall burning decreased yield by about 30 percent the first year after burning with no significant reduction thereafter. The wheatgrass type (western wheatgrass-thickspike wheatgrass) was more detrimentally affected than the communities dominated by blue grama and needle-and-thread. Vegetation did not recover as rapidly on grazed pastures as on the ungrazed experimental plots. It took 3 to 5 years for a burned and grazed pasture to regain normal productivity. The vegetation response is similar to that reported by Hopkins and others (1948) and Launchbaugh (1964) in the shortgrass prairie of the central and southern Great Plains.

Research results indicate no apparent benefits from burning herbaceous species in the arid mixed prairie where wheatgrasses predominate. Research done on needle-and-thread and green needlegrass is inadequate to determine response to prescribed fire. However, data from Coupland (1973) and comments by Clarke and others (1943) lead us to believe that the needlegrasses are not as detrimentally affected by fire as are the wheatgrasses. On the other hand, fire will kill silver sagebrush (Rowe 1969), fringed sage, and little club moss (Dix 1960), and will reduce the vigor of western snowberry. Research data indicate that more than 3 years must be allowed for full recovery of the range under grazing (Clarke and others 1943). Such a long rest would be a high price to pay for shrub control and may not be necessary. Precipitation on the northern Great Plains follows dry and wet cycles. Prescribed burning may be a useful management tool for the control of shrubs and little club moss following winters with above normal precipitation. Only meticulous research will provide the answers.

FIRE EFFECTS - MESIC MIXED PRAIRIE [Precipitation 15 to 18 inches (38 to 48 cm)/year in United States; precipitation may be as low as 13 inches (33 cm) in Canada]

Dix (1960) studied the effect of three wildfires (May, August, September - all subject to trespass grazing) in western North Dakota where annual precipitation averaged 16 inches (41 cm). He found that a hot, late-May wildfire reduced the frequency of bearded wheatgrass, blue grama, prairie sandreed, needle-and-thread, and green needlegrass. The frequency remained the same or higher for western wheatgrass, low sedge, threadleaf sedge, Pennsylvania sedge, junegrass, and Plains muhly. However, herbage yield might have been reduced for several years. Frequencies of fringed sage, Arkansas rose, and silverleaf scurfpea were significantly reduced, whereas most forbs remained unchanged. Following a fall burn, the long-term evaluations (4 years), showed relatively few changes in botanical composition except for a possible reduction in threadleaf sedge, fringed sage, leafy spurge (*Euphorbia esula*), and little club moss. *Hedeoma hispida*, stickseed (*Lappula redowski*), and herbaceous sage increased. Pennsylvania sedge, prairie sandreed, hairy golden-aster, and wild lettuce were harmed by the late summer fire, but no explanation was given.

On a similar mixed prairie site in Wind Cave National Park in South Dakota, Schripsema (1977) found that an early spring burn (April 21, 1976) increased western wheatgrass, needle-and-thread, buffalograss, and blue grama. Green needlegrass, bluegrasses, and forbs decreased, whereas sedges showed no change. Yields following the same burn in a drier year (1977) showed similar trends except for decreases in needle-and-thread and sedges. Forb composition was similar to the controls. Thus, green needlegrass and the exotic bluegrasses are quite susceptible to early spring burns, but most other grasses are tolerant of such burns if there is moisture in the soil at the time of the burn.

Bluestem sites of the forest-grass ecotone in the Black Hills area (fig. 15) are more tolerant of prescribed fires (Gartner and Thompson 1972; Schripsema 1977). Annual precipitation is 15 to 17 inches (38 to 43 cm). A late spring burn (May 27, 1976) increased little bluestem 31 percent, big bluestem 20 percent, forbs 108 to 405 percent, and decreased bluegrasses 65 percent (Schripsema 1977). Silverleaf scurfpea and slim-flowered scurfpea were two forbs that increased noticeably. Minor amounts of western wheatgrass, buffalograss, and blue grama and needlegrasses were present. Western wheatgrass decreased and the other species increased. On the other hand, a winter burn (March 1, 1977) had almost the reverse effect. Big and little bluestem were severely harmed. Western wheatgrass and the needlegrasses increased, and bluegrasses were reduced only 28 percent. Thus, late spring burns during years with normal to above-average precipitation are the most preferable to increase herbaceous yields of desirable grasses and achieve desired compositional changes.

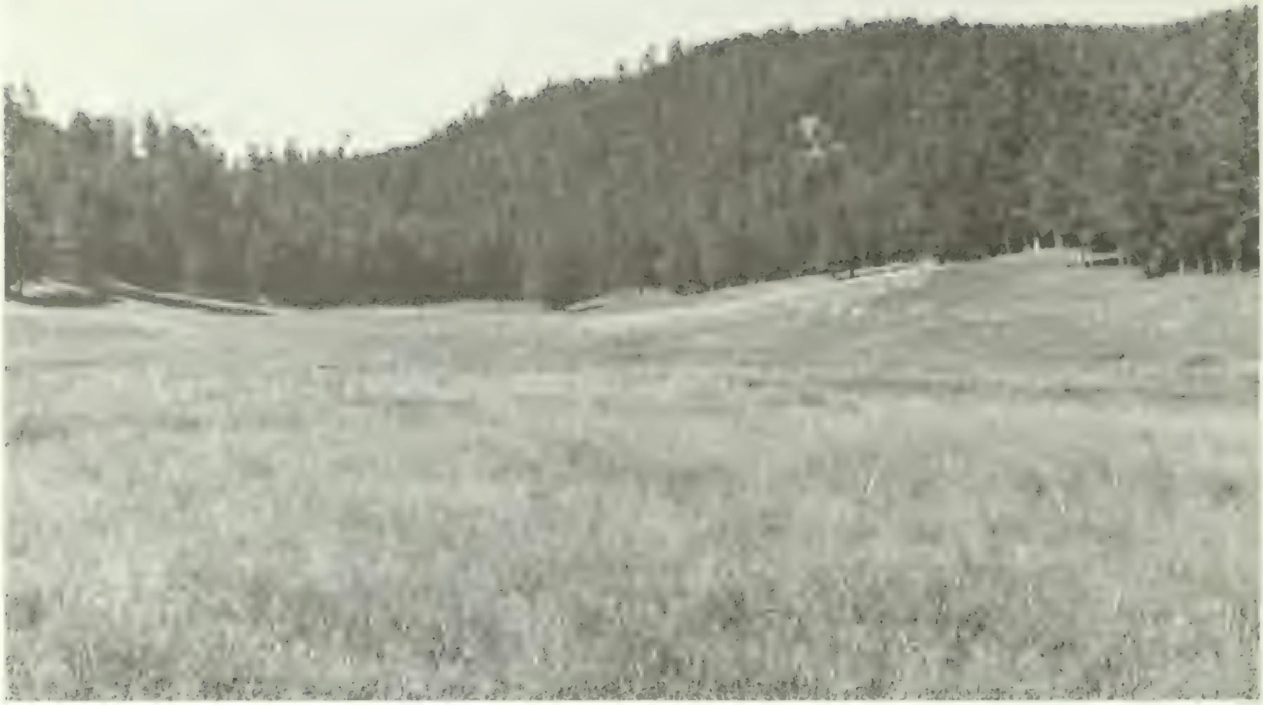

Figure 15.--Mixed prairie that borders the Black Hills of South Dakota. Little bluestem and big bluestem are the dominant grasses. Fire can be used in this vegetation to keep young pines from spreading into the grasslands.

Kirsch and Kruse (1972) studied the effects of prescribed spring fire on vegetation at the extreme eastern edge of the mixed prairie in east-central North Dakota, near the tallgrass prairie. Annual precipitation averages 17.5 inches (44 cm). Their purpose in burning was to improve wildlife habitat. The warm season grasses, big and little bluestem, prairie sandreed, blue grama, and Leiberg panicum (*Panicum leibergii*) increased in cover after burning. So did the three needlegrasses, needle-and-thread, western porcupine grass, and green needlegrass. Bearded and western wheatgrass maintained themselves with burning but declined in unburned areas (Kirsch, Wildlife Biologist, U.S. Fish and Wildl. Serv., Woodworth, N.D., personal communication). Kentucky bluegrass had high foliar cover before burning in 1969 but was nearly eliminated by three consecutive fires. Quackgrass and smooth bromegrass continued to expand on unburned plots but were not present on burned plots.

Most forbs either increased in cover or did not change. Major forb increasers after burning included western ragweed, meadow anemone (*Anemone canadensis*), candle anemone (*A. cylindrica*), prairie crocus (*A. patens*), heath aster, prairie chickweed (*Cerastium arvense*), Maximilian sunflower (*Helianthus maximiliani*), purple prairie clover, and silverleaf scurfpea. Most other forbs, including western yarrow, herbaceous sage, bedstraw, and goldenrod did not change appreciably. The shrubs, fringed sage, prairie rose, and western snowberry, also did not change appreciably. Canada thistle decreased greatly after burning.

FIRE EFFECTS - TALLGRASS PRAIRIE

A classic account of the effect of fire on tallgrass prairie concerns rejuvenation of the Curtis Prairie in Wisconsin (Curtis and Partch 1948; R. Anderson 1972). This particular area was abandoned from cultivation in 1932. By 1936 the principal perennials were quackgrass, Kentucky bluegrass, and Canada bluegrass (Curtis and Partch 1948). Various annuals were also present. A number of prairie forbs and grasses were transplanted into the area in 1936 and 1937 at a density of 2.6 plants per 100 ft^2 (2.8 plants per 10 m^2). It was soon evident that the species were not maintaining themselves against the bluegrass sod. Fire was introduced experimentally to test the desirability of burning, the best season and frequency of burning. Since 1950, one-half to two-thirds of the 20-acre (8.1-ha) prairie has been burned every year.

Annual burning between 1941 and 1946 reduced bluegrass sod by 80 percent and permitted big bluestem, rattlesnake master (*Eryngium yuccifolium*), goldenrod (*Solidago rigida*), tall gayfeather (*Liatris aspera*), common ragweed (*Ambrosia artemisiifolia*), heath aster, and erigeron (*Erigeron annua*) to increase. Atlantic wildindigo (*Baptisia leucantha*) was not affected by fire and purple coneflower (*Echinacia purpurea*) was the only species reduced by burning. A more recent botanical composition evaluation of the prairie from Cottam and Wilson (1966) illustrates the increase in big bluestem, little bluestem, Indiangrass, *Solidago* sp., *Eryngium* sp., *Lactuca* sp., tall gayfeather, *Ratibida* sp., and *Silphium* sp. (table 4). Quackgrass and Kentucky bluegrass were still declining as of 1961. Wild parsnip (*Pastinace sativa*), a troublesome weedy species, is also declining (R. Anderson 1972).

Table 4.--*Frequency of plant species in Curtis Prairie, Stand A, 1951 and 1961*[1]

	Frequency	
	1951	1961
	- - - - - - - - -*Percent*- - - - - - - - -	
Prairie species		
Achillea millefolium	44	55
Ambrosia artemisiifolia	79	53
Andropogon gerardi	6	44
Andropogon scoparius	—	47
Aslepias verticillata	59	61
Eryngium yuccifolium	1	69
Helianthus grosseseratus	--	5
Lactuca canadensis	48	84
Liatris aspera	2	37
Monarda fistulosa	53	73
Ratibida pinnata	6	32
Rudbeckia hirta	—	5
Silphium terebinthinacium	2	21
Solidago gigantea	--	3
Solidago nemoralis	--	81
Solidago rigida	--	8
Sorghastrum nutans	--	68
Other species		
Agrostis alba	--	8
Aster pilosus	71	31
Pastinaca sativa	32	11
Poa compressa	79	97
Solidago altissima	32	48
Weeds		
Agropyron repens	29	11
Oxalis stricta	54	44
Poa pratensis	60	13
Trifolium repens	74	43

[1] Data from Cottam and Wilson (1966).

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Hadley (1970) reported an increase in big bluestem and little bluestem, and a decrease in Kentucky bluegrass following one spring burn in eastern North Dakota. Other species that increased were prairie dropseed, prairie cordgrass, saltgrass (*Distichlis stricta*), western snowberry, and Arkansas rose. Wheatgrass increased on upland sites but declined on lowland sites. Those species that declined were porcupine grass, needle-and-thread, *Poa* sp., *Muhlenbergia* sp., foxtail barley, prairie clover, and heath aster. All of these data were based on yields taken in 1966, a drier than normal year (Hadley 1970). Total herbage yield was 2,980 lb/acre (3,348 kg/ha) on the unburned plot and 3,833 lb/acre (4,307 kg/ha) on the burned plot.

Total production of herbage on the Curtis Prairie in Wisconsin 1 year after burning was 8,478 lb/acre (9,526 kg/ha) compared to 4,180 lb/acre (4,697 kg/ha) on the unburned site (R. Anderson 1972). Similar differences for the same prairie have been shown by Peet and others (1975). Removal of litter, and increased soil temperatures and daylight in early spring were the main factors contributing to the increased plant growth.

Scrub oak (*Quercus ellipoidalis*) is very abundant in Wisconsin prairies that had been protected from fire for 25 to 80 years (Vogl 1967).

FIRE EFFECTS - FESCUE PRAIRIE

The complexity of fire effects on fescue prairie does not allow a simple assessment of relative detriment and benefits in the Rocky Mountain foothills and the plains area of the aspen parkland (Bailey 1978). Prescribed burning research is very recent and much is still unpublished. Wildfires reduced forage production, plant vigor, basal area, leaf length, and number of flowering culms in the rough fescue - Parry's oatgrass community in the foothills of southwestern Alberta (Johnston, Range Scientist, Agric. Res. Stn., Lethbridge, Alberta, personal communication). A mid-April 1976 prescribed burn, prior to growth of rough fescue, maintained forage production, reduced basal area, leaf length, and number of flowering culms in the first year when growing season precipitation was normal (Klumph, Range Management Specialist, Energy and Nat. Res., Lethbridge, Alberta, personal communication). The second year, when precipitation was below normal, forage production was significantly higher on burned areas than on unburned areas.

A July wildfire near Missoula, Mont., decreased cover and frequency of bluebunch wheatgrass and Idaho fescue, but cover and frequency of rough fescue was maintained (Mitchell 1958).

The foothill ecotypes of rough fescue were 2 to 3 ft (0.6 to 0.9 m) tall and have 8- to 20-inch (20- to 51-cm) diameter bunches (Moss and Campbell 1947). Response of the big bunches to burning depends upon severity of the fire. Mitchell (1958) observed a tall stubble on the burned rough fescue clumps. This stubble insulated the crown from an excessive rise in temperature during burning. He attributed the cause of the maintenance of rough fescue and decline in Idaho fescue and bluebunch wheatgrass under burning to differences in crown characteristics. The fire burned closer to the crown of Idaho fescue and bluebunch wheatgrass.

Not all fires burn the foothill ecotypes of rough fescue in the same manner as reported by Mitchell (1958). Wright (1971) found that a bunchgrass with high density of fine fuels maintained the heat longer within the clump than did one with coarse culms and a lower density of fine fuels. Under certain conditions, severe damage and high mortality can be inflicted upon a big bunchgrass like rough fescue. The fire may burn down into the crowns of rough fescue clumps under very dry conditions. A backfire, a slow-moving headfire, or continued burning of clumps after the fire front passes may generate hot fires within plants resulting in a high mortality. Apparently, Idaho fescue's growth form is more susceptible to continuous burning after the passage of a flame front than is rough fescue or bluebunch wheatgrass (Wright and Britton 1976). The latter two grasses develop larger bunches, coarser stems, and less fine fuel close to the growing point than does Idaho fescue. According to Conrad and Poulton (1966), a hot July wildfire in northeastern Oregon killed many more Idaho fescue plants than bluebunch wheatgrass plants.

A complex relationship exists between prescribed fire and rough fescue-western porcupine grass communities on the plains of central Alberta (Bailey and Anderson 1978). The first growing season after early spring or late fall burning, total herbage yields were the same as the unburned control [1,050 to 1,215 lb/acre (1,180 to 1 365 kg/ha)]. However, there were significant changes in plant composition (table 5). Spring burning reduced foliar cover 22 percent and seed production of rough fescue 97 percent; but fall burning was detrimental to western porcupine grass, particularly number of seed heads (reduced 97 percent). Cool season plants such as sedge and Hooker's oatgrass were reduced by spring fire. Fire usually increased cover and frequency of most forbs. The half-shrub, fringed sage, was reduced by both fires.

Table 5.--*Canopy coverage (percent) and plant frequency (percent) in fescue grassland following prescribed burning (data from M. Anderson 1972; Bailey and Anderson 1978)*

Species	Unburned		Burned			
			Fall		Spring	
	Cover	Frequency	Cover	Frequency	Cover	Frequency
Rough fescue	[1]84a	100	79b	100	62c	100
Western porcupine grass	86a	100	79b	100	84a	100
Hooker oatgrass	18a	56	6b	52	1b	68
Sedge	54a	100	55a	100	44b	100
Bearded wheatgrass	6	31	4	34	8	57
Milk vetch	4	32	12	77	11	60
Three-flowered avens	1b	7	11a	62	10a	58
Smooth aster	1	13	3	46	6	55
Western yarrow	1b	15	2a	24	4a	50
Prairie crocus	7	59	7	61	8	57
Pasture sage	3a	26	<0.5b	3	<0.5b	2

[1] Values within a row followed by the same letter are not significatly ($P < 0.05$) different.

Another year, when spring growth was initiated earlier and burning was conducted when rough fescue leaves were about 4 inches (10 cm) tall, rough fescue, bearded wheatgrass, and slender wheatgrass cover was reduced by 60 percent the first growing season. It took 3 years for the species to recover. Perennial forbs more than doubled, particularly milk vetch (*Astragalus striatus, A. flexusus*), three-flowered avens (*Geum triflorum*), and western yarrow.

In a related study, M. Anderson and Bailey (1979) burned dense colonies of western snowberry that grow in patches on the grasslands. One year after spring burning, there was increased cover of perennial forbs, including American vetch, vetchling (*Lathyrus ochroleucus, L. venosus*), woundwort (*Stachys palustris* var. *pilosa*), northern bedstraw, and herbaceous sage. An annual forb, Russian pigweed (*Axyris amaranthoides*), grew only in burned areas the first year after burning and decreased during the second and third years.

Shrubs responded the same to fire whether they were burned in the spring or fall (Bailey and Anderson 1978). Silverberry and fringed sage were seriously harmed. Rose and western snowberry were moderately harmed (M. Anderson and Bailey 1979; Bailey and Anderson 1978). Herbaceous sage and raspberry (*Rubus strigosus*) increased dramatically.

Early spring burning in one area of central Alberta has been conducted annually over the past 25 to 30 years (H. Anderson and Bailey 1980). Preliminary results show that the frequency (percentage) of all shrubs--silverberry, rose, aspen, serviceberry, and chokecherry--is higher on the burned than on unburned plots. Frequency of western snowberry remained the same, and only prickly rose (*Rosa scidularis*) decreased. However, cover of all shrubs, except for herbaceous sage, was reduced 83 percent by annual burning The high frequency yet low cover of shrubs seems to be indicative of a fire environment for tenacious shrubs.

Grasses and forbs that increased under the long-term burning program included prairie sandreed, sedge (*Carex obtusata, C. heliophila*), Missouri goldenrod, buffalobean, western yarrow, and bedstraw. Rough fescue and western porcupine grass decreased.

Based on present knowledge, fire apparently has the potential to remove litter buildup on ungrazed fescue grassland and to control shrubs with only moderate damage to the grasses. Forage losses can be minimized by using fire only during those springs that are preceded by above-normal precipitation. The desired interval for use of fire to control shrubs is probably 5 to 10 years. More judicious use of these ranges by cattle, sheep, and game in combination with burning may enhance the healthiness of these grasslands.

BENEFICIAL EFFECTS OF FIRE IN PRAIRIE GRASSLANDS

Where fire is an appropriate management tool, the major benefits of prescribed burning in grasslands are to control undesirable shrubs and trees, burn dead debris, increase herbage yields, increase utilization of coarse grasses, increase availability of forage, improve wildlife habitat (more food with unburned patches for cover), and to control cool season species where warm season grasses are dominant (Wright 1974a). Several objectives can be achieved simultaneously with one burn, the major advantage of using fire as a management tool.

When large amounts of litter cause stagnation, in the tallgrass and southern mixed prairie grasslands, fire is an effective tool for increasing plant growth (Weaver and Rowland 1952; Kucera and Ehrenreich 1962; Peet and others 1975; Sharrow and Wright 1977a) Removal of the litter permits soil temperatures to rise 10° to 30°F (6° to 17°C) in early spring (Peet and others 1975), which stimulates nitrification by bacteria (Sharrow and Wright 1977a). The high population of soil bacteria after fire (Neuenschwander 1976) decomposes organic matter to produce additional nitrates. This sequence of events, plus optimum growing temperatures created by the bare soil, allows warm season plants to grow at an optimum rate if moisture is adequate (Sharrow and Wright 1977a, 1977b). Thus, most of the fertilizing effect after a fire comes from nitrates released when bacteria consume organic matter, not from nutrients in ash (Old 1969; Sharrow and Wright 1977a).

The young, tender growth after fire is naturally more palatable and easily accessible to livestock and wildlife. It enables us to use fire effectively to attract livestock to grasses that are normally too coarse and contain too much litter to be palatable. Undesirable cool season grasses and forbs can be reduced with spring burns. Forbs, which provide an important food source for many upland game birds, are frequently more readily available on burned areas (Kirsch and Kruse 1972). Resprouts of shrubs are not only more accessible but may be more nutritious up to 3 years after the burn.

Controlling shrubs in the mixed prairie, tallgrass prairie, and fescue prairie is a major objective for using fire. Fire can be used to top-kill mesquite, completely kill 25 percent of the mesquite on upland sites, kill 50 percent to 80 percent of all cactus species, and kill Ashe juniper (Britton and Wright 1971; Wink and Wright 1973; Wright and others 1976a; Bunting and others 1979). Bragg and Hulbert (1976) have shown conclusive evidence that without fire the tallgrass prairie is easily invaded by shrubs and trees. Preliminary findings on an area burned for 25 consecutive years in central Alberta indicate that fire can be used to reduce cover of shrubs and trees (H. Anderson and Bailey 1980).

In the shortgrass prairie and semi-arid northern mixed prairie [less than 13 to 15 inches (33 to 38 cm) of annual precipitation], the use of fire does not appear to produce major beneficial effects, except in very special situations where it is desirable to control shrubs, improve livestock distribution, or remove litter that has stagnated plant growth.

POTENTIAL IMPACTS OF FIRE IN PRAIRIE GRASSLANDS

Detrimental effects of fire are generally associated with its misapplication. For example, if burning is conducted during dry years from fall to early spring under wildfire conditions, desirable herbaceous species are seriously harmed and have less than normal herbage yields for at least 2 years. This is especially true in the shortgrass and arid portions of the mixed prairie. In the northern Great Plains, more cool season species such as *Stipa* sp. and *Agropyron* sp. are encountered. These species may be harmed for 2 to 5 years, depending upon season of burn and whether the plants are under moisture stress.

Nevertheless, dry years are often best for long-term effectiveness in killing some shrubs when there are minimum amounts of fine fuel. Eliminating juniper species is a good example. Fire may be needed only every 20 to 30 years to control juniper, and burning during droughts can be tolerated if the ranges are rested from grazing until herbaceous species have fully recovered.

Erosion following fires is not likely to be a serious problem unless the slopes are steeper than 20 percent (Wright and others 1976b) or the soils are sandy. Sandy soils are subject to wind erosion when protective plant cover is removed. If burning is considered desirable on such soils, low-intensity fires should be used and burning planned so that a mosaic of unburned areas remains.

Smoke can be objectionable near highways and populated areas. Burning should be done when there is a steep adiabatic lapse rate (daytime) so that the smoke will rise and disperse at high altitudes. Burning should be done when winds are blowing away from nearby towns. Nighttime burning is particularly undesirable because smoke will drift and settle in low-lying valleys and stay there until the middle of the next day. These situations can lead to complaints to pollution boards and cause further restrictions on burning. Such incidents can be avoided by burning within the prescribed burning regulations and by burning as rapidly as possible. Most people will tolerate smoke for a few hours, but not for several days.

Fire should not be used more frequently than every 5 to 10 years in the western and central portions of the Great Plains. Long-term declines in production of grasses as a result of burning more frequently have been documented (Neuenschwander 1976). As one goes eastward and the precipitation increases, fire frequency may be every 1 to 3 years without harming the grasses (Anderson and others 1970).

MANAGEMENT IMPLICATIONS

Shortgrass Prairie

Fire has few uses in the shortgrass prairie. The grasses do not benefit from burning. They tolerate fire without loss in forage during wet years (Trlica and Schuster 1969; Heirman and Wright 1973; Wright 1974b), but are moderately to severely harmed for 2 to 3 years when precipitation is below normal (Hopkins and others 1948; Launchbaugh 1964; Dwyer and Pieper 1967). Nevertheless, prescribed burns can be used to clean up chained debris and kill pricklypear and other *Opuntia* species less than 2 ft (0.6 m) tall (Heirman and Wright 1973). In eastern New Mexico prescribed fires can be used to control small juniper trees (Dwyer and Pieper 1967). Fire also will increase herbage production on sand shinnery oak range in good condition (McIlvain and Armstrong 1968).

Mixed Prairie

CENTRAL AND SOUTHERN GREAT PLAINS

Prescribed fire has a wide variety of uses in the mixed prairie. Fire is especiall useful in the southern and central portions to increase production and palatability of coarse grasses such as tobosagrass and little bluestem that have a tendency to accumulat litter. Most grasses tolerate fire well during years with normal to above-normal precipitation, exceptions being sideoats grama and Texas wintergrass (Wright 1974b). Cool-season annuals such as little barley and Carolina canarygrass are also severely harmed. Spring fires kill many undesirable forbs--i.e., annual broomweed--and cool-season annuals, minimizing competition for the warm-season perennials. Thus the warmer soil increases nitrates and reduces competition from "weeds," which provides an ideal environment for growth of warm season grasses if soil moisture is adequate. Fire can be used in the southern mixed prairie on a 5- to 8-year frequency (Sharrow and Wright 1977b).

Fire is effective for burning standing dead honey mesquite stems (Britton and Wright 1971) and killing some honey mesquite (Wright and others 1976a). Green honey mesquite trees are difficult to kill. Fire may also be used to kill 50 to 80 percent of the cactus (*Opuntia* sp.) (Bunting and others 1980), clean up chained debris (Wright 1972a), remove dead piles of Ashe juniper, kill young Ashe juniper trees (Wink and Wright 1973), remove brush to ease handling of livestock, and in some cases, improve wildlife habitat.

Generally, pastures should be burned on a manageable unit basis, unless tobosagrass is dominant. About 10 to 20 percent of each tobosagrass pasture should be burned each year on a rotational basis. Cattle should be grazing the burned area 2 to 3 weeks after a fire in spring and fall, taking the pressure off other grasses. Animals will not graz burned tobosagrass in summer or winter. It is desirable, therefore, to have both burned and unburned areas in tobosagrass pastures.

NORTHERN GREAT PLAINS

In the northern mixed prairie, information for the semi-arid areas [10 to 15 inches (25 to 38 cm) annual precipiation] indicates there may be only a limited place for fire as a management tool. However, fire is capable of killing silver sagebrush, fringed sage, Japanese bromegrass, and little club moss. More data are needed on the desired frequency of burning. Prescribed burning should probably be conducted in this region only following winters with above-average precipitation. Fall burning appears to have the most promise for not injuring desirable forage species (Clarke and others 1943).

In the more mesic areas [16 to 20 inches (41 to 51 cm) annual precipitation] of the northern mixed prairie, cool-season grasses (except for slender wheatgrass and smooth bromegrass) were more tolerant of fire than in the semi-arid mixed prairie. The warm-season grasses (little bluestem and big bluestem) benefit from burning (Kirsch and Kruse 1972). Shrubs (i.e., *Symphoricarpos occidentalis*) can be set back by fire (M. Anderson and Bailey 1979) and ponderosa pine seedlings can be killed (Gartner and Thompson 1972).

Periodic prescribed burning in fescue grassland will improve cattle distribution by removing litter on ungrazed slopes. Because shrubs are only set back by one burn, reburns or herbicide treatments are required to keep them in check. The effect of fire on wildlife is unknown. Prescribed burning probably should be done only during normal or wet years. Not enough research has been done to establish a reasonable estimate of burning frequency.

Tallgrass Prairie

The primary reasons for burning in the tallgrass prairie are to increase production and palatibility, improve nutritional value of tallgrasses, suppress encroachment of trees and shrubs, and reduce competition from undesirable cool season plants such as Kentucky bluegrass and smooth bromegrass. Annual burns do not appear to harm the native warm-season species if burned in late spring (Anderson and others 1970). Less frequent burns benefit all of the major tallgrass species--big bluestem, little bluestem, Indiangrass, and switchgrass--(Hensel 1923; Aldous 1934; Dix and Butler 1954; Robocker and Miller 1955; Kucera and Ehrenreich 1962; Hadley and Kieckhefer 1963; McMurphy and Anderson 1965; Hulbert 1969).

Exotic cool-season grasses are severely harmed by spring burning. Many researchers (Hensel 1923; Enrenreich 1959; Hadley and Kieckhefer 1963; Old 1969) have found that Kentucky bluegrass decreases 80 percent or more following a spring burn. Curtis and Partch (1950) found that Canada bluegrass and Kentucky bluegrass were severely damaged by spring burning. Similarly, Canada wildrye, Virginia wildrye (Robocker and Miller 1955), Japanese brome (McMurphy and Anderson 1965), and smooth bromegrass (Old 1969) are moderately damaged by fire. Species such as smooth bromegrass, which begins growth about mid-May, are only inhibited by burning, whereas species such as Kentucky bluegrass are almost eliminated by burning because they begin growth in early April (Old 1969).

Late spring (May 1) burning reduces all forbs (McMurphy and Anderson 1965), although the composition of forbs is changed relatively little (Anderson 1965). Kucera (1970) proposed a 3-year interval between burning to maintain dominance of warm season grasses, as well as to retain species diversity typical of the native prairie community.

Woody plants will invade a prairie protected from disturbances such as fire (Kucera 1960; Penfound 1964; Vogl 1967; Blan 1970; Bragg and Hulbert 1976). Thus, it seems reasonable that fire should be an effective tool to control woody plants. Although research results are limited, it appears that fire properly used will control woody plants. Annual burning during May controlled coralberry in Kansas (McMurphy and Anderson 1965). Pelton (1953) felt that periodic burning would favor western snowberry in Minnesota, but that annual burning would harm it.

PRESCRIBED BURNING GUIDES

General Comments

One cannot learn how to ride a bicycle by just reading printed instructions. One must get on the bicycle and practice. However, once the basics of riding a bike have been learned, the novice rider can read or listen to more experienced riders in order to improve his riding, increase efficiency of effort, safety, speed, ease, comfort, and satisifcation. The same is true for learning how to conduct prescribed burns.

There is a lot of art to prescribed burning. There are also many unforeseen circumstances peculiar to each burn. Nevertheless, experience is the best teacher. We learn by doing, and by doing, we learn rapidly. A wildfire can be frightening, but prescribed burning is not as dangerous as wildfire. Prescribed burning is dangerous to the inexperienced. It is very dangerous to those not fully experienced, for these are the persons who become overconfident and may have fires get away.

Models for prescriptions can be helpful in the planning phases of a burn, but they do not protect you against the intangibles--a hill on the side of a pasture that might cause unusual winds, a canyon on the lee side that may aid the formation of an intense firewhirl that will throw firebrands at greater distances than normal, unusual fuel densities that can create intense firewhirls, possibility of a nighttime low-level jet of wind, or volatile fuel material. Most people who conduct rangeland burns consider most fire danger index models to be too complicated and too time consuming to be useful. They usually use two to four critical variables to make a decision as to whether to burn.

The secret to all prescribed burning is to let the weather work for you. When all environmental factors are right, the job is easy. However, if the relative humidity is below 20 percent, if you are depending on a low pressure trough in late afternoon for your wind direction, if air temperature is above 80°F (27°C), or if average windspeeds are above 15 mi/h (24 km/h), prescribed burning can be a miserable job. On the other hand, do not be too cautious. Set a fire that will accomplish your objectives. The prescription that we like for most headfires is a relative humidity of 25 to 40 percent, air temperature 70° to 75°F (21° to 24°C), and wind 8 to 15 m/h (13 to 24 km/h). For backfires, you can burn under considerably cooler conditions, depending on amount of fine fuel and fine fuel moisture levels.

In volatile fuels, most firebrands ignite on punky wood, a cow chip, or lodge in a crack of bark, wood, or tight clump of grass. Punky wood and cow chips are by far of the greatest concern. The best defense is high humidity and a wide fireline. For example, a glowing ember has rarely been seen to start a fire when the relative humidity was above 50 percent. Below a relative humidity of 25 percent, potential for spot fires is great. Therefore, to burn on the high side of the 25 to 40 percent range minimizes danger from firebrands. Consumption of dead material, particularly standing material, will be reduced considerably if you burn with a relative humidity above 40 percent.

Low windspeeds [below 6 mi/h (10 km/h)] also reduce the risk of glowing firebrands starting spot fires. Unless prescribed burning windspeeds are above 8 mi/h (13 km/h) in grasslands, woody material will not ignite easily and if ignited may go out. This is especially applicable to standing material.

Relative humidity is related to temperature, but we have had a tendency to rely more heavily on relative humidity than temperature. However, 67°F (19°C) seems to be a threshold value. Below this temperature we usually get incomplete burns of woody materials. Above 75°F (24°C) we must be very careful. We do not recommend burning when the air temperature is above 80°F (27°C).

Every fire is different and confidence grows as one gains experience in a fuel type. If inexperienced in a certain vegetative type, seek out the best information available. Write a fire plan and a prescription for the planned burn (Fischer 1978). Burn a small area and start when conditions favor control--45 to 60 percent relative humidity, wind less than 6 mi/h, air temperature of 40° to 60°F (4° to 16°C). Burn in late afternoon or early evening when you know the relative humidity is on the rise. Experiment with a few small burns; learn something about fire behavior and the combustibility of various types of fuel. Document weather, amount of fine fuel, and fuel moisture for each burn.

Mixed Prairie with Honey Mesquite

(Low Volatile Fuel)

Detailed prescriptions for conducting burns in low volatile (mesquite-tobosagrass) and high volatile (Ashe juniper) fuels have been given by Wright (1974a). Depending on the objectives, a wide variety of prescriptions can be used and experience is always the best teacher. For example, if you want to clean up chained debris in buffalograss that has 2,000 lb/acre (2,247 kg/ha) of fine fuel, burn a 100-ft (30-m) wide fireline on the north and east sides when the relative humidity is 30 to 50 percent, wind is 5 to 10 mi/h (8 to 16 km/h), and air temperature is 60° to 75°F (16° to 24°C). Burn the rest of the pasture with a headfire when the relative humidity is 20 to 40 percent, wind is out of the southwest at 8 to 15 mi/h (13 to 24 km/h), and air temperature is 70° to 75°F (21° to 24°C).

If dead mesquite is standing and you wish to burn it, you need a minimum of 3,000 lb/acre (3,371 kg/ha) of fine fuel, relative himidity below 40 percent, and wind in excess of 8 mi/h (13 km/h). Burn a 100-ft (30-m) wide fireline on the north and east sides when the relative humidity is 50 to 60 percent and the wind is less than 8 mi/h (13 km/h). Headfire the rest of the pasture with a southwest wind when the relative humidity is 25 to 40 percent, wind is 8 to 15 mi/h (13 to 24 km/h), and air temperature is 70° to 75°F (21° to 24°C) (fig. 16).

The primary dangers in burning grasslands come from tumbleweeds and firewhirls. Tumbleweeds will ignite and then tumble, leaving flames in their path. Firewhirls develop where wind shears occur, such as when a headfire runs into a backfire, or a fire goes up slope into a wind. We have seen several firewhirls develop when headfires met backfires while winds were 10 to 15 mi/h (16 to 24 km/h). We have also seen two huge firewhirls develop when winds were light and variable. For these reasons, we prefer to burn with a steady wind and never burn into backfires, unless we have at least a 300-ft (91-m) fireline. Burning should be done with ridges, not across them.

Mixed Prairie with Juniper

(High Volatile Fuel)

Firebrands are a serious problem when burning chained or piled dead juniper. Thus, for safety, we need to burn out a 400-ft (122-m) fireline on the north and east sides of a pasture (fig. 17). Burn out the dead piles of brush when the grass is green (May to early June), the wind is less than 10 mi/h (16 km/h), and the relative humidity is above 45 percent. Later (January and Fegruary), burn out the bluestem grass in the firelines when the relative humidity is 50 to 60 percent and the wind is less than 8 mi/h (13 km/h). Nonflaming firebrands are rarely a problem when the relative humidity is above 50 percent (Bunting and Wright 1974). Where buffalograss occurs, more wind and less humidity are required.

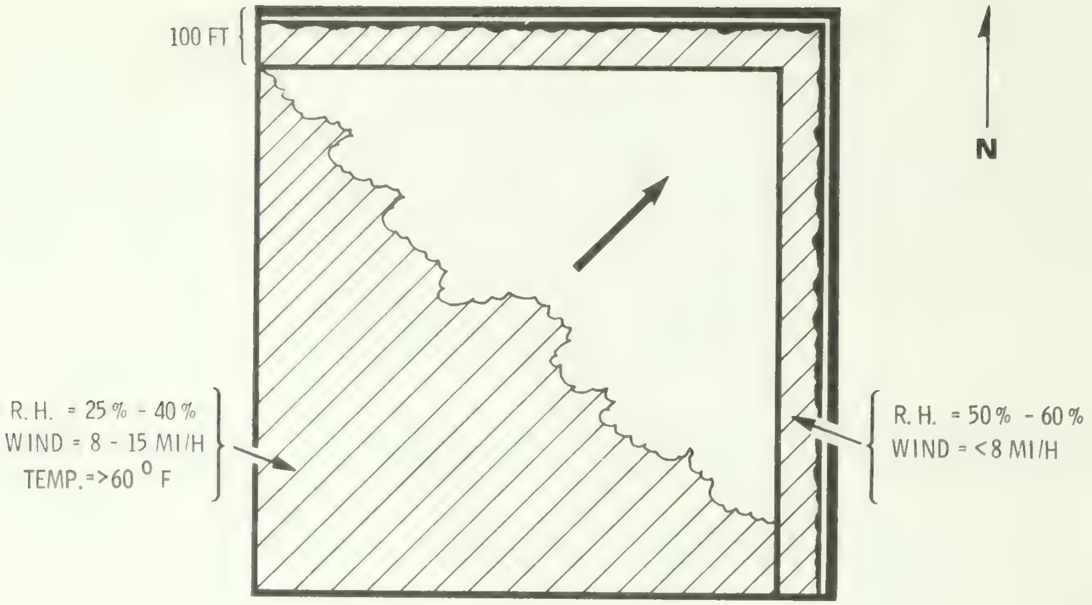

Figure 16.--Fire plan for fuels of low volatility. After firelines are cut, a 100-ft (30-m) strip on the downwind sides (north and east) of a pasture is backfired with winds less than 8 mi/h (13 km/h) and with relative humidities between 50 and 60 percent. Then the pasture is headfire with the prevailing wind (southwest) averaging from 8 to 15 mi/h (13 to 24 km/h) and relative humidities from 25 to 40 percent.

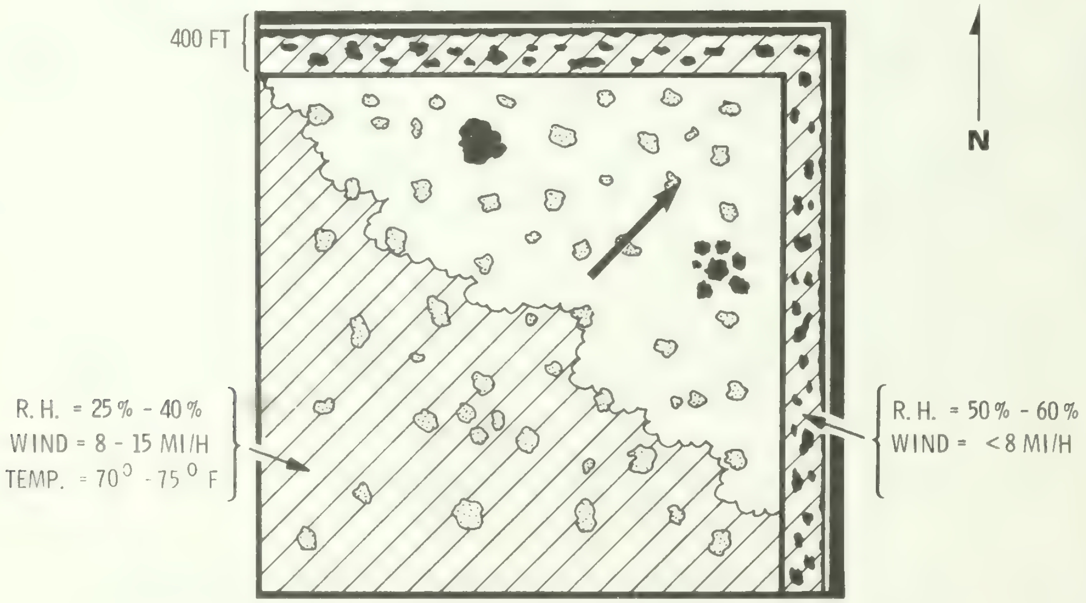

Figure 17.--Fire plan for fuels of high volatility. When the grass is green, juniper piles in the 400-ft (122-m) strip (black splotches) on the downwind sides (north and east) are burned with wind velocities less than 10 mi/h (13 km/h) and relative humidity above 45 percent. Eight months later (when grass is dormant), the grass in the 400-ft (122-m) strip is burned when the wind is less than 8 mi/h (13 km/h) and relative humidity is between 50 and 60 percent. Lower relative humidities may be used if the grass fuel is less than 2,000 lb/acre (2,247 kg/ha). All large concentrations of piles are backfire on the downwind sides of main area to be burned, and then the entire area is burned into the prepared firelines with a wind of 8 to 15 mi/h (12 to 24 km/h) and a relative humidity of 25 to 40 percent.

After the fireline is burned out, burn the rest of the area with a southwest wind when the relative humidity is 25 to 40 percent, wind is 8 to 15 mi/h (13 to 24 km/h), and air temperature is 65° to 75°F (18° to 24°C). After a rain, wait at least 5 days to burn.

For safety, avoid burning backfires into headfires and avoid burning across ridges. Firewhirls can easily develop in those situations. In highly volatile fuels such as juniper, burn into heavily grazed pastures, when possible, to minimize risk. In this fuel type, one should have at least two seasons of burning experience before assuming responsibility for conducting a burn.

To burn grasslands with young, green juniper trees [2 to 5 ft (0.6 to 1.5 m) tall], one can use much smaller firelines--about 50 ft (15 m). In these cases cut a 10-ft (3-m) fireline around the entire pasture. Then burn out 50 ft (15 m) on the lee sides in late evening or early morning and put the fire out on the windward side with a pumper.

Sand Shinnery Oak with Little Bluestem

(Moderately Volatile)

Burning techniques for this type in Oklahoma have not been documented. Generally there is enough grass to permit a backfire to burn back through the shinnery under cool conditions [i.e., relative humidity 50 to 60 percent, air temperature 60°F (16°C), and wind 5 to 10 mi/h (8 to 16 km/h)]. In many cases the fire will go out as it backs up. After a 200- to 300-ft (61- to 91-m) fireline has been burned, then the area can be headfired.

Refinement of technique is needed in this fuel type. Oak leaves act as firebrands, so one must be reasonably careful. However, based on our experience, we have never had trouble with oak leaves starting spot fires beyond 66 ft (20 m). We suspect that a 200-ft (61-m) fireline would be adequate for headfires when the relative humidity is 25 to 40 percent, wind is 5 to 10 mi/h (8 to 16 km/h), and air temperature is 70° to 75°F (21° to 24°C). With 2,000 to 4,000 lb/acre (2,247 to 4,494 kg/ha) of fine fuel, cooler conditions would give satisfactory burns. Based on volatile fuel data, the firelines should be burned when the relative humidity is above 50 percent, wind less than 8 mi/h (13 km/h), and air temperature is 45° to 65°F (7° to 18°C). The high humidity would be especially important to minimize danger from firebrands.

Firelines should be cut around the area to be burned, but the inside of the 200-ft (61-m) strips could be natural breaks. Often the fire will go out when backing up, and a pumper could be used to put out the spots that continue to burn.

Tallgrass Prairie

In the tallgrass prairie, particularly the Flint Hills region, many ranchers have burned for years and know how to do it. Launchbaugh and Owensby (1978) have written a bulletin that contains prescription burning guidelines for the State of Kansas. The authors state that firebrands are not a problem, except for some areas with eastern redcedar. Humidity in this area is usually 50 to 60 percent, so burning is relatively safe. Fine fuel is continuous and may be as much as 3,000 to 4,000 lb/acre (3,371 to 4,494 kg/ha).

Launchbaugh and Owensby begin burning on the leeward sides of a pasture and let the fire back into the pasture. Two spray rigs patrol and lay down a wet line when necessary. Usually, the authors can backfire from a trail or road. They rarely plow permanent firelines. After the fire has backed up 100 to 150 ft (30 to 46 m), they headfire the rest of the pasture. Headfires are set with 5 to 10 mi/h winds (8 to 16 km/h)if improvement of forage quality is the only concern. Where brush control is important, the authors recommend burning in winds from 5 to 15 mi/h (8 to 24 km/h) and when relative humidity is about 40 percent. Ambient temperature is not important, but generally varies from 60° to 75°F (16° to 24°C).

Where tall eastern redcedar (fig. 18) is to be burned, Launchbaugh and Owensby usually rest the pasture to be assured of 3,000 to 4,000 lb/acre (3,371 to 4,494 kg/ha) of fine fuel. Then they burn out a 100- to 200-ft (30- to 61-m) fireline late in the evening or early in the morning when dew is on the grass. After the fireline has been burned, the authors set a headfire, with winds up to 15 mi/h (24 km/h) and low humidity (40 percent or so). Coralberry has not produced troublesome firebrands, so no special preparations are needed when this shrub is present.

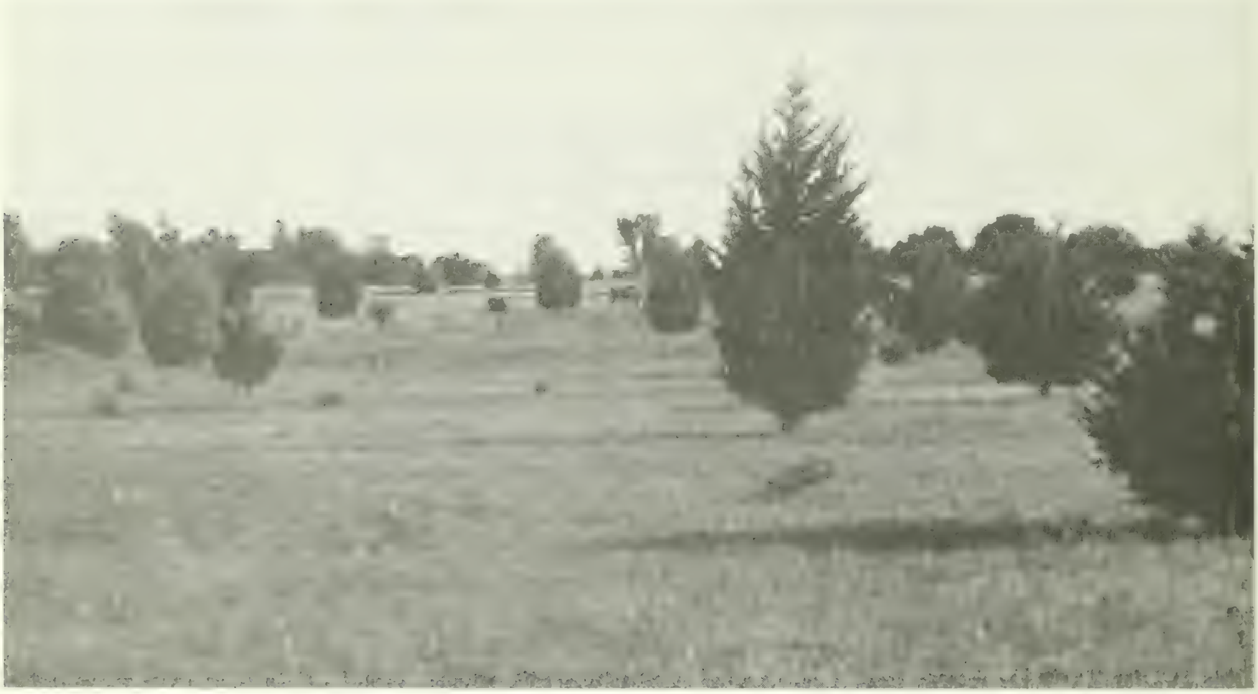

Figure 18.--Fire can be used in the tallgrass prairie to control redcedar. Trees less than 4 ft (1.22 m) tall are easily controlled with fire. To kill trees taller than 4 ft (1.22 m), one must have at least 2,000 lb/acre (2,247 kg/ha) of grass and burn with 10 to 15 mi/h (16 to 24 km/h) winds.

Marsh Burns

Marshes are usually burned to reduce the density of reeds, create new feeding areas, and to create more edge effect for nesting areas. In the north-central Nebraska Sandhills, Schlichtemeier (1967) found that thick, dense stands of marsh could easily be burned. Excellent results were achieved after ice was 9 to 12 inches (23 to 30 cm) thick and 2 to 4 inches (5 to 10 cm) of snow covered the surrounding range. Four burns were conducted in January and February under the conditions shown in table 6. Combustibility of vegetation varied only slightly on all four burns. Density of reed (*Phragmites communis*) and bulrush (*Scirpus* sp.) decreased 85 to 60 percent. Schlichtemeier (1967) burned successfully in freezing weather, because marshes have large quantities of dry material in thick layers partially protected from the weather. Light or moderate grass fuels will not burn under similar conditions.

Table 6.--*Prescriptions for four burns in a reed marsh in north-central Nebraska*[1]

Burn no.	Relative humidity	Temperature		Wind	
	Percent	*°F*	*°C*	*Mi/h*	*Km/h*
1	72	30	-1	15	24
2	60	37	3	7	11
3	67	17	-8	23	37
4	52	42	6	17	27

[1] Data from Schlichtemeier (1967).

Fescue Prairie and Aspen Parkland

(Low to Highly Volatile Fuels)

Western snowberry, willows, and dead aspen are volatile fuels and produce abundant firebrands. Firebrands ignite dung piles, which cause spot fires, most frequently when the relative humidity is below 25 percent. Consequently, grasslands that have few shrubs or trees are usually comparatively safe to burn.

Snow is an advantage to spring burning in mesic areas of the northern Great Plains. Grasslands melt free from snow several weeks before adjacent shrublands and forest. Grasslands can then be burned a few days after snowmelt, with the wet forest and shrublands or a plowed line 12 to 14 ft (3.7 to 4.3 m) wide acting as a fireline. Several weeks later the green grassland is an effective fireline when the shrubland and forest are burned.

The weather conditions required for safe burning in the Alberta aspen parkland are presented in table 7. The aspen forest and snowberry shrublands have been successfully burned only with headfires. The prescription for grass fires will need to be altered as fine fuel decreases. For example, if you were to burn grazed rough fescue, the relative humidity may need to be as low as 25 to 40 percent, wind 8 to 12 mi/h (13 to 19 km/h), and air temperature 50° to 70°F (10° to 21°C). A few small test burns will help one determine the desired range of weather conditions.

Dung piles are the major cause of spot fires. Firebrands from woody plants land n the cracks of dung piles. Dung piles exposed to bright sunshine and low humidity may smolder for hours and then ignite adjacent fine fuels. Horse dung is particularly angerous because it is round. As it burns, it becomes lighter and may roll in the wind, igniting fine fuels as it travels.

Table 7.--*Weather conditions required for successful spring burning in the central Alberta aspen parkland*

Vegetative type	Minimum temperature		Wind		Maximum relative humidity	Drying time
	°F	°C	Mi/h	Km/h	Percent	Days
Fescue grassland	45	7	2-12	3-19	65	1
Snowberry shrubland	55	13	2-12	3-19	50	4
Aspen forest[1]	59	15	4-12	6-19	40	10
Aspen forest[2]	64	18	8-16	13-26	30	14

[1] Few spot fires, but only 25 to 50 percent of the forest will burn when relative humidity is 30 to 40 percent.

[2] Spot fires will be numerous, requiring a 400-ft (122-m) fireline downwind, but 80 to 100 percent of the forest will burn when relative humidity is 10 to 30 percent.

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APPENDIX--SUMMARY OF FIRE EFFECTS DATA

SOUTHERN GREAT PLAINS

Shortgrass Prairie

Growth form	*Species*	*Fire effects*	*Remarks*
Grasses	Buffalograss	Decreased for 2 to 3 yr after burning during drought yr; buffalograss and blue grama not harmed when winter and spring precipitation are above normal.	
	Blue grama		
	Red threeawn	Generally decreased by fire.	
	Sand dropseed	Generally decreased by fire.	But tolerant when winter and spring precipitation were 40 percent above normal.
	Galleta	Generally decreased by fire.	Based on data from wildfire during a below average precipitation year.
	Ring muhly		
	Slim-stemmed muhly		
	Wolftail		
	Little bluestem	Production decreased after burn.	Based on data from sand shinnery oak areas in Oklahoma.
	Tumble windmill grass	Not harmed by fire.	
	Sand bluestem	Production increased after burn.	Based on data from sand shinnery oak areas in Oklahoma.
	Switchgrass	Production increased after burn.	
	Weeping lovegrass	Not harmed by fire.	
Forbs	Annual broomweed	Harmed by spring burning.	Generally, forbs are harmed more by spring burns than fall burns.
	Horsetail conyza		
	Silverleaf nightshade		
	Western ragweed		
	Multistem evax	Not affected by spring burning.	
	Warty euphorbia		
	Woolly plantago		
	False mesquite	Favored by spring burning.	

SOUTHERN GREAT PLAINS

Growth form	*Species*	*Fire effects*	*Remarks*
		Shortgrass Prairie	
Shrubs	Mesquite	Fire tolerant.	Exceptional sprouters, especially on the High Plains. Seedlings are reasonably tolerant of fire when more than 1 yr old. A February burn reportedly killed 31 percent of seedlings less than 1 yr old. Repeated burns will keep mesquite in check.
	Shinnery oak	Fire tolerant.	Increased 15 percent following fire, but produced no acorns during year of burn.
	Algerita) Aromatic sumac) Chickasaw plum) Fourwing saltbush) Skunkbush sumac) Winterfat)	Fire tolerant sprouters.	Fourwing saltbush is palatable and is fully recovered 3 yr after being burned.
	Sand sage	Fire tolerant sprouter.	Resprouts after fire and produces abundant seedlings after burning.
	Cacti (*Opuntia*)	Fire intolerant.	50 to 80 percent of most species are killed, especially if they are less than 2 ft tall. Large clumps of prickly-pear or tall cholla usually survive fires.
		Mixed Prairie	
Grasses	Sideoats grama (rhizomatous form)	Harmed.	More tolerant in wet years - yield decreased 51 percent in dry years vs. 12 percent in wet years. Takes at least 3 yr to recover after being burned during dry years.
	Little bluestem	Tolerance is moisture dependent.	Decreases about 50 percent following burning in dry years, but will increase as much as 81 percent during wet years after a spring burn.
	Tobosagrass	Very tolerant.	Burning increases production twofold to threefold and palatability tenfold when precipitation is average or higher. When precipitation is below average, yields may be reduced 20 to 50 percent. Never burn more than one-fifth to one-eighth of a pasture each year.

SOUTHERN GREAT PLAINS

Mixed Prairie

Growth form	*Species*	*Fire effects*	*Remarks*
Grasses	Arizona cottontop) Meadow dropseed) Plains bristlegrass) Texas cupgrass) Vine mesquite)	Tolerant.	Thrive after fire when moisture is adequate. Vine mesquite shows increased yields for 2 years; Arizona cottontop for 1 year.
	Tall grama	Intolerant.	Tolerates fire after burns in wet years; declines as much as 60 percent during dry years.
	Sideoats grama-) bunchgrass form)	Tolerant.	
	Texas wintergrass	Intolerant.	Severely harmed by broadcast fires, but favored by cool, creeping spring ground fires.
	Little barley) Carolina canary grass)	Intolerant of spring burning.	Cool season annual grasses.
Forbs	Annual broomweed) Bitterweed) Scarlet globemallow) Wild onion)	Intolerant.	
	Annual sunflower) Carolina horsenettle) Lambsquarter) Silverleaf nightshade)	Common on burns.	
	Plains dozedaisy) Redseed plantain)	Tolerant.	Second season after burning plains dozedaisy and redseed plantain reach maximum importance value.
	Perennial ragweed)	Tolerant.	
	Goldenrod)	Tolerant.	

SOUTHERN GREAT PLAINS

Mixed Prairie

Growth form	*Species*	*Fire effects*	*Remarks*
Trees & Shrubs	Mesquite	Tolerance dependent on age, stand history, weather, fire intensity.	Green mesquite tolerant except when very young. With temperatures greater than 260°C, plants up to 1.5 yr are easily killed; 2.5-yr-old plants are severely harmed; plants 3.5 yr and older are very tolerant. Trees previously top-killed (drought, herbicides, etc.) are moderately harmed--25 percent mortality on upland sites; none along river bottoms.
	Eastern redcedar	Intolerant.	Non-sprouter - leaves very flammable; bark very thin; seedlings abundant after fire.
	Ashe juniper	Intolerant.	Non-sprouter - leaves very flammable; bark very thin; seedlings abundant after fire. Amount of mortality depends on amount of fine fuel and fire intensity. Minimum of 700 to 1,000 lb/acre (786 to 1,124 kg/ha) of fine fuel needed to kill trees 2 to 4 ft (0.6 to 1.2 m) high. With 2,500 lb/acre (2,809 kg/ha) or more, all juniper trees will be killed.
	Redberry juniper	Tolerant when over 12 yr old.	Sprouter. Fire reduces "sphere of influence" - permits grasses and forbs to become established closer to trees.
	Lotebush	Tolerant; regrowth is slow until fourth year after burning.	Sprouter - regains prefire position in about 6 to 10 yr after fire.
	Fourwing saltbush	Very tolerant.	Palatable species, vigorous sprouter - fully recovered 3 yr after burn.
	Algerita Little leaf sumac Oak	Tolerant.	Sprouters - little research data available.
	Smoothleaf sumac	Very tolerant.	Usually comes back on the hottest areas of a burn; vigorous sprouter.
	Cacti	Intolerant.	Frequently present in high densities in mesquite-tobosa communities. Easily killed by fire (50-80 percent mortality). Fire acts as agent to initiate interactions that result in mortality; e.g., insect activity, rodent activity, drought.

SOUTHERN GREAT PLAINS

Mixed Tallgrass-Forest

Growth form	*Species*	*Fire effects*	*Remarks*
Grass	Little bluestem	Tolerant.	No fire research has been done. There is current interest in using fire on a 4-yr rotation to keep oak sprouts suppressed in bluestem pastures. Considering this precipitation zone, and based on fire effects data from other areas, little bluestem should be very tolerant of fire.
Trees	Blackjack oak Post oak	Easily top-killed but resprout vigorously.	

CENTRAL GREAT PLAINS

Tallgrass Prairie

Growth form	*Species*	*Fire effects*	*Remarks*
Grasses	Canada bluegrass	Severely harmed.	Generally an 80 percent reduction. Cool season species.
	Kentucky bluegrass		
	Canada wildrye	Harmed.	Smooth brome is more tolerant of early spring burns than other cool season species because it does not germinate until mid-May.
	Japanese brome		
	Smooth brome		
	Virginia wildrye		
	Fall witchgrass	Favored.	
Forbs	Dotted gayfeather	Tolerant.	Most species favored by fire, but some people have reported declines for prairie clover and goldenrod.
	False boneset		
	Missouri goldenrod		
	Plains wild indigo		
	Prairie sunflower		
	Silky prairie clover		
	Goosefoot	Harmed.	
	Gromwell		
	Heath aster		
	Pepperweed		
	Pigweed		
	Prairie coneflower		
	Virginia day flower		
	Woolly plantain		
Shrubs	Missouri spurge	Unchanged.	
	Western ragweed		

CENTRAL GREAT PLAINS

Short Grass and Mixed Prairie

Growth form	*Species*	*Fire effects*	*Remarks*
Grasses	Buffalograss Blue grama Western wheatgrass	Allow 2 to 3 yr for recovery during dry years; not harmed when precipitation is above normal.	Buffalograss-blue grama mixture recovered 55, 62, and 97 percent following the first, second, and third growing seasons after being burned in the spring during a dry year. Western wheatgrass recovered 18, 27, and 77 percent, respectively, during the same growing seasons.
	Big bluestem Hairy grama Hairy sporobolus Little bluestem Sideoats grama	Harmed by fire during dry years.	No data for wet years, but would probably tolerate fire.
Forbs	See data for Southern Great Plains		
		Tallgrass Prairie	
Grasses	Big bluestem Indiangrass Little bluestem Switchgrass	Very tolerant.	Production often doubles after burning, unless burned annually. If burned annually, burns should be conducted about May 1. Drought is rarely a problem in this rainfall belt.
	Blue grama Buffalograss Hairy grama Prairie junegrass Prairie sand dropseed Sideoats grama	Generally no change to a slight increase.	

Mixed Grass Prairie

Growth form	*Species*	*Fire effects*	*Remarks*
Grasses	Bearded wheatgrass Green needlegrass	Frequency reduced by spring burning.	
	Pennsylvania sedge Prairie sandreed	Frequency unchanged by spring burning, but harmed by late summer fires.	
	Blue grama *Carex eleocharis* Junegrass Muhlenbergia Needle-and-thread Threadleaf sedge Western wheatgrass	Frequency unchanged or increased by early spring burning.	Increase in frequency does not necessarily imply increase in herbage yield, which might be reduced for several years. Late spring burning harms western wheatgrass.
	Big bluestem Little bluestem	Probably not harmed by fire and could be burned during years with normal to above normal precipitation to control scrubby ponderosa pine and undesirable shrubs.	
Forbs	Silverleaf scurfpea Slim-flowered scurfpea	Increases and decreases have been reported following spring burning.	Frequencies of most forbs remained unchanged after spring burning.
	Leafy spurge Little club moss	Frequency reduced by fall burn.	Data taken 4 yr after a fall fire.
	Hairy golden aster Wild lettuce	Harmed by late summer fire.	
	Hedeoma hispida Stickseed	Increased after fall burning.	Data taken 4 yr after a fall fire.

NORTHERN GREAT PLAINS

Mixed Grass Prairie

Growth form	*Species*	*Fire effects*	*Remarks*
Shrubs	Arkansas rose)		
	Fringed sagebrush)	Reduced by spring burning.	
	Silver sagebrush)		
	Herbaceous sage)	Increased after spring burning.	
		Tallgrass Prairie (True Prairie)	
Grasses	Big bluestem)		Some of this information is based on frequency data and may or may not reflect yields.
	Blue grama)		
	Indiangrass)		
	Leiberg panicum)		
	Little bluestem)	Increase after spring burning.	
	Prairie cordgrass)		Eastern North Dakota study.
	Prairie dropseed)		
	Prairie sandreed)		
	Saltgrass)		
	Wheatgrasses	Increased on upland sites, but declined on lowland sites.	
	Bearded wheatgrass)		
	Canada bluegrass)		
	Foxtail barley)		
	Junegrass)		
	Kentucky bluegrass)	Usually harmed by fire, but some data show no change and some show an increase.	
	Muhlenbergia sp.)		
	Quackgrass)		
	Rushes)		
	Slender wheatgrass)		
	Smooth brome)		

Tallgrass Prairie (True Prairie)

Growth form	*Species*	*Fire effects*	*Remarks*
Forbs	Erigeron Goldenrod Common ragweed Rattlesnake master	Increase after spring burning.	See table 3 of text for other forbs that increase after burning.
	Atlantic wild indigo	No change.	
	Heath aster	Variable responses.	Declined in eastern North Dakota, but increased with spring burning in Wisconsin.
	Canada thistle *Oxalis stricta* Prairie clover Purple coneflower *Trifolium repens* Wild parsnip	Declined after spring burning.	
Shrubs & Trees	Arkansas rose Western snowberry	Increase after spring burning.	
	Scrub oak	Increases with fire exclusion.	

FESCUE GRASSLANDS

Growth form	Species	Fire effects	Remarks
Grasses	Agropyron-type communities Blue grama - Needle-and-thread communities	Reduced yields up to 50 percent following spring burning during a dry year. Effects of fall burning less pronounced - production decreased by 30% first year with recovery second year.	Agropyron type communities are more sensitive to spring burning than blue grama and needle-and-thread.
	Bearded wheatgrass Slender wheatgrass Western porcupine grass	No change in cover after spring burn with good moisture; fall burns harmful.	Fall burning severely harmed the wheatgrasses. Western porcupine grass was reduced 25 to 50 percent by fall burns.
	Prairie sandreed Sedge	Increased with annual spring burn.	
	Hooker's oatgrass Parry oatgrass Rough fescue Sedge Timothy	Harmed by spring burning.	Rough fescue required 3 yr for full recovery. It tolerates fall burns better than spring burns.
Forbs	Bedstraw Buffalobean Milk vetch Missouri goldenrod Stickseed Three-flowered avens Western yarrow Woundwort	Increased after spring and/or fall burning.	
	Little club moss	Seriously harmed by spring and fall burns.	
Shrubs	Fringed sage Silverberry	Seriously harmed by spring and fall burns.	
	Silver sagebrush Arkansas rose Prickly rose Western snowberry	Moderately harmed.	Desired frequency for shrub control is probably 5 to 10 yr. Forage losses can be minimized by using fire only during those springs preceded by normal to above normal precipitation.
	Herbaceous sage Raspberry	Increased dramatically.	

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1980. Fire ecology and prescribed buring in the Great Plains--a research review. USDA For. Serv. Gen. Tech. Rep. INT-77, 61 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

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The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

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Report INT-78

February 1982

Static Testing to Evaluate Airtanker Delivery Performance

Aylmer D. Blakely, Charles W. George, and Gregg M. Johnson

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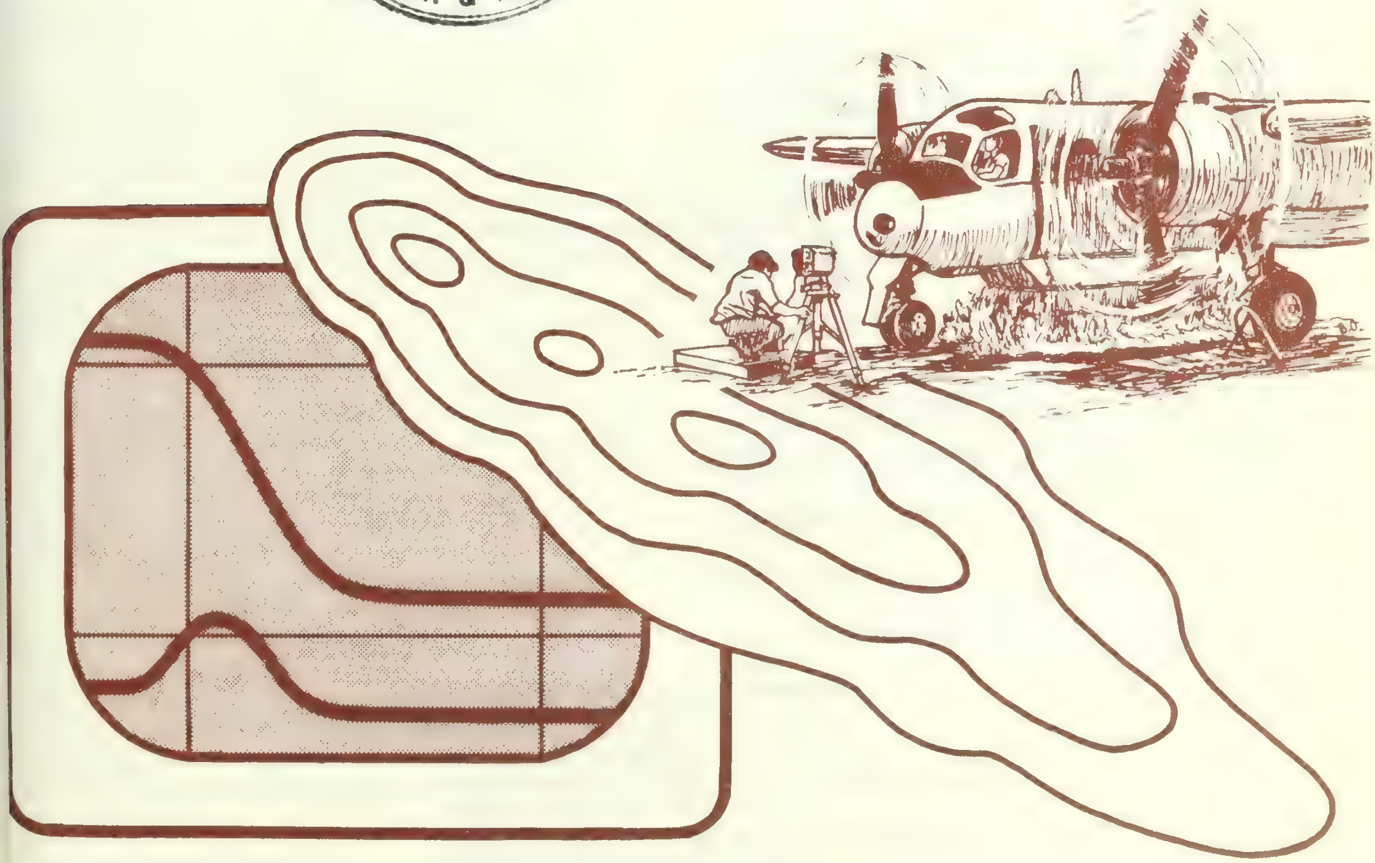

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RESEARCH SUMMARY

A number of airtanker performance guides have been developed by the USDA Forest Service and in cooperatio with the Honeywell Corporation. These guides predict fir retardant ground distribution patterns resulting from various drop configurations that are possible with each tank and gating system. The guides were developed using a computer simulation model (PATSIM) and a number of inputs from a "static test" of the selected airtanker.

This report details the tank and gating system preparation and description needed to determine the static test matrix and for inclusion in the simulation. The data collection and analysis procedures are given in detail for reducing the data to a form that is usable for input to PATSIM.

Following procedures outlined in this report will make it possible to determine the expected performance of an airtanker for which a guide is unavailable by comparing its static test data with that of other airtankers for which guides have been prepared.

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Static Testing to Evaluate Airtanker Delivery Performance

Aylmer D. Blakely, Charles W. George, and Gregg M. Johnson

ntroduction

Innumerable retardant and water drops have been ade on wildfires when neither the firefighters on the ound nor the airtanker pilot knew whether or not the tardant would get to the fire or what effect it would ave. Consequently, numerous drop tests have been con- ucted to quantify the drop patterns of airtankers and tardants (USDA Forest Service 1955; Davis 1959; Storey nd others 1959; Johansen and Shimmel 1967; Grigel 70; George and Blakely 1973; George 1975; and wanson and others 1978). In an attempt to mathemati- ally simulate the air drop performance of aircraft, acPherson (1968) developed a model that predicted ealized patterns based on tank geometry, tank door pening speed, aircraft speed, and drop height. The simu- tion model, however, was applicable only to aircraft aking drops at relatively low drop speeds and heights 5 to 110 knots and 50 ft [15.2 m] to 100 ft [30.5 m] above ound). Utilizing the MacPherson model and actual drop attern data available for several airtankers, Swanson nd Helvig (1974) expanded the model to include the fects of the retardant physical properties on breakup nd evaporation (thickened versus waterlike retardants) nd refined the effects of drop height and airspeed. The odel was altered to predict ground distribution patterns well as summarize the results of incremental releases. omparisons of predicted and actual performance at the various stages of model development indicated that acceptable estimates of patterns could be made by empirically tuning the model and inputting an actual flow rate of retardant from the tank (an adequate mathematical link between tank geometry and flow rate was not attained).

Swanson and others (1975, 1977), under contract to USDA Forest Service, utilized the pattern simulation model (PATSIM) with actual retardant flow rate data to develop the first user guides for several selected airtankers. The guides (Swanson and others 1977) are a summary of data for different drop conditions and configurations, compiled and simplified in graphs and tables than can help airtanker pilots, air attack specialists, and ground personnel use delivery systems most efficiently. A number of these guides have been prepared in notebook form as "Airtanker Performance Guides" and are presently in use.[1]

The purpose of this report is to outline procedures and provide instructions for collecting the flow rate data necessary for developing performance guides for selected airtankers.

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[1] U. S. Department of Agriculture, Forest Service. 1977. Airtanker performance guides. Report on file at the Northern Forest Fire Laboratory, Missoula, Mont.

Static Testing

A procedure for measuring the flow rate of retardant or water from an airtanker has been developed and termed "Static Testing." This involves the quantification of flow rates while the aircraft is parked, as opposed to tests conducted while the aircraft is in flight (fig. 1 shows an airtanker undergoing static testing). During the development of static test methods, water and retardant were dropped from the same tank and gating system while the aircraft was parked on the ramp and during flight. These tests indicated that no significant difference in the flow rates existed for water or retardant (thickened Phos-Chek XA or unthickened Fire-Trol 931-L) whether the aircraft was parked on the ramp or in flight, provided certain conditions were met. The necessary conditions included: (1) the aircraft being situated in a "near flight attitude" and (2) having similar tank door-opening speeds when the aircraft is in the static position and in flight (the door opening speed is related to the method of opening the doors and/or the power source for opening the doors, that is, using aircraft engine power, hydraulic or pneumatic pressure systems, or simply gravity). Accordingly, the flow rate data needed to predict airtanker performance using the pattern simulation program PATSIM can be collected by "static testing" the aircraft tank and gating system with water as the retardant medium. Obtaining the flow rate data in this manner avoids the extra time and dollars necessary to conduct drop tests for determi ing airtanker performance. To determine the performanc of a delivery system by in-flight testing, a large number flights are necessary to vary the drop heights and speed plus utilize all possible tank and gate drop combination Static test data, the computer, and the PATSIM simulation model make possible a thorough test series that ca examine a wide range of velocities, drop heights, and retardant types in only a few days. The usual time needed for two or three persons to perform "static tests on a single aircraft delivery system is 2 to 3 days, depending on its complexity.

Static test data is gathered with mechanical and/or electronic sensing devices placed within the tanks and on the tank doors. The primary parameter measured during static testing is the fluid flow history (rate of discharge) as it exits the tank. This is usually measured by monitoring floats that follow the upper surface of the fluid when the tank doors are opened.

Flow rate is the only parameter needed as a tank and gate system input to PATSIM. Other parameters such a door open angle (as a function of time) and tank venting (pressure) are measured to provide insight to the relativ importance of system variables and as indicators for

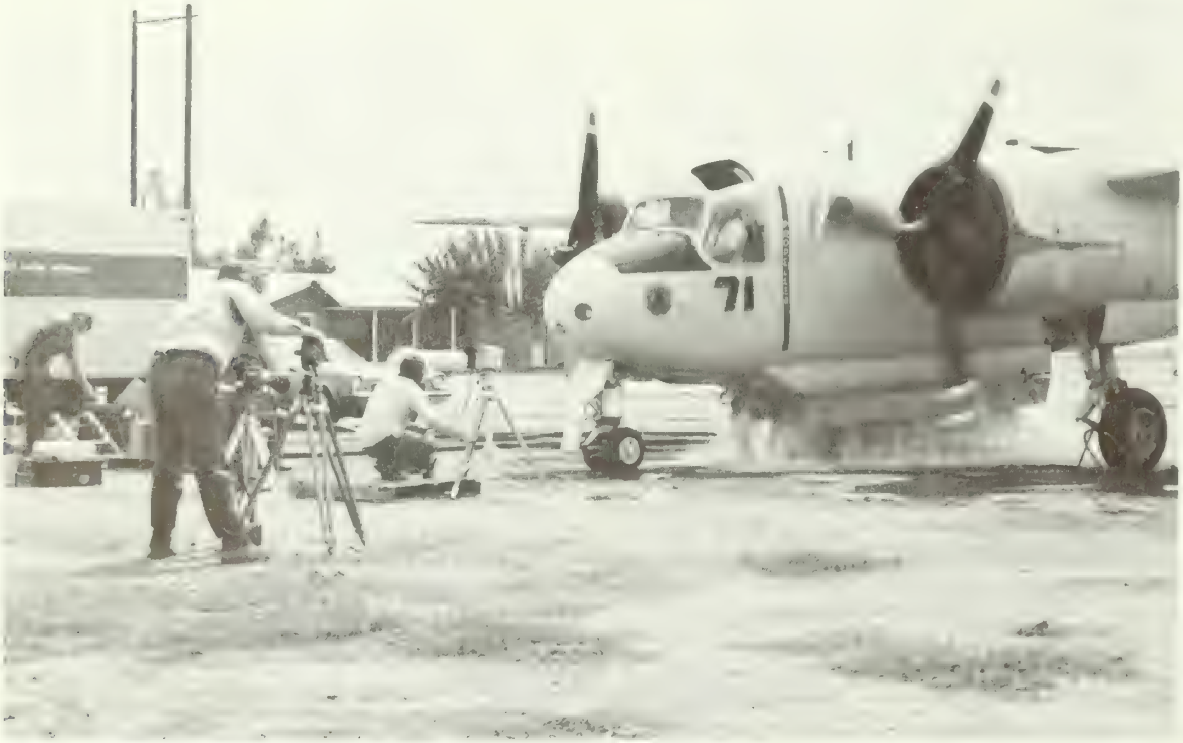


Figure 1.—Static testing a California Division of Forestry S2F airtanker. Notice it was necessary to run the engines to obtain representative door opening times.

ouble shooting and determining the adequacy of data. or example, if inadequate venting exists, the float data ill be inaccurate if a partial vacuum causes the fluid urface to slow or stop thereby affecting the float. Open- g the doors with and without the engines running can etermine whether or not the doors will open at the same te during both static tests and in flight.

During static tests, initial results often indicate de- very system performance limitations or shortcomings. It not uncommon for airtanker operators to respond to ese test results and make on-site modifications during e tests to improve the performance of their tank and ate system. Although such action is desirable, it is nportant that such modifications be completed prior to ollecting final static test/system performance data.

rocedures

The procedures for conducting static tests on airtanker elivery systems have been developed by experimenta- on. Many variations exist between tank and gate ystems presently in the airtanker fleet, that is, door- pening and closing mechanisms, tank configuration, ethods of venting, and so on. These variations often require modification of procedures and adapting available strumentation.

Procedures have also been modified to be compatible ith other static testing objectives. For example, in some stances it has been possible to collect the necessary ata to develop airtanker performance guides while conducting an evaluation of a newly developed tank and ating system. To check mandatory design and/or per- rmance criteria established by the Interagency irtanker Board (appendix A) for new systems, much of e same data gathered during static testing is required. onsequently, the static test methods discussed here ave been adopted for evaluation of new delivery ystems.

The procedures outlined in this publication are tended to be fairly specific, yet provide the basis for an nderstanding of the relationship between primary riables while pointing out various external factors that ay have a significant effect on the outcome of the sts. Because of the large number of variables and ctors influencing static test results and tank and gate stem performance, it is not practical or possible to tablish a rigid, ordered static test procedure. The test atrix selected must be based on recognition of the imary influencing factors. The procedures have been vided into three major areas or tasks, and a discussion each follows.

nk and Gating System Preparation

Prior to conducting static tests, several questions d/or influencing factors must be considered and dealt th. The primary goal of the preparation is to assure at the performance of the tank and gating system der static conditions will be similar to its in-flight per- rmance and that the test configuration and data col- cted will be accurate and reflect conditions existing ring operational use. Primary considerations include e following:

Tank Integrity - *Significant loss of fluid from the tank, either internal or external, can influence the rate of change of the fluid surface (which correlates to flow rate) when a compartment release is made. External leaks from a compartment or tank are easily detected visually, but internal leaks are more obscure. Flow to or from a compartment that is adjacent to a compartment being released (that is, through leaks in the tank seams, unclosed cross flow openings or flapper doors, or loading manifolds) can significantly affect the fluid level and flow rate calculations. (Such leaks can also adversely affect operational performance; for example, poorly sealed cross flow doors installed for loading purposes can result in intercompartmental flow after partial drops. As a result, pilots could unknowingly return to base with part of the retardant load.) Therefore, leaking or cross flow should be minimized to increase the accuracy of the fluid level history during a release. A leak is significant if it causes the fluid level in a measured or adjacent tank to drop more than one-half inch (12.7 mm) during preparation for the drop or during the drop (noted by observing the fluid level in the measured or adjacent tank).*

Tank Configuration/Sequence - *The normal operational drop configurations or sequences should be determined since the number of drop combinations will dictate the static test matrix chosen. The most desirable drop configurations as outlined in the mandatory tank and gate criteria (appendix A) and by Swanson and Luedecke (1978) ("Tank Design Guide") should be considered at this point. Minor electrical changes in the tank and gating intervalometer system can sometimes be made to improve drop pattern performance and make the system conform to new requirements. If such changes are anticipated, it is best to incorporate them prior to static testing since they will alter performance and can, depending on the magnitude of the change, invalidate the data and the performance guide being developed.*

In-Flight Aircraft Attitude - *The attitude of the aircraft tank and gating system can affect volume distribution in compartments within the tank (especially long tanks) and affect the accuracy of measurements of fluid flow rate from the tank. This will depend on the instrumentation used to monitor the liquid level and its location in the compartment. Therefore, it is necessary to estimate the in-flight attitude and determine if it is significantly different when the aircraft is in a parked position (the largest differences usually exist for aircraft which sit on a tail wheel). This adjustment is often subjective, but usually the airtanker is positioned with the tank bottom approximately level. Wheel struts may be adjusted or a tail jack used to elevate the aircraft tail (for example, the tail of B-17 aircraft must be raised 3 ft [0.91 m] to 4 ft [1.22 m] as shown in fig. 2).*

Describing the Tank and Gating System

In addition to preparing the tank and gating system for static testing and after preliminary checks are completed, several measurements must be made to determine which compartments must be instrumented. To collect sufficient data to build an accurate performance guide, it is necessary to instrument and test all tank compartments, singles or combinations, **that have different flow rates.** Usually, it will not be necessary to static test every compartment in a tank and gate system. Wasted time and effort will be avoided if only compartments having significantly different performance are tested. A good description of the tank and gate system will assist in determining which compartments or conditions can be expected to yield different performance, that is, flow rates.

There are several parameters that should be quantified and considered when looking for probable differences in compartment flow rates; compartment size and geometry, vent access, and door opening rates and angles. The description of the tank and gating system should include (1) door opening area measurements, (2) compartment dimensions, (3) compartment volumes, and (4) marks at water levels for different approved loads/down loads (head height). (The tank geometry and dimensions are used in developing an algorithm to determine the volume discharged at any given time during the drop from which flow rate is calculated.) The spatial arrangement of the compartments is noted in order to provide a "near scale" drawing of the tank and gating system (for inclusion in the performance guide [as shown in fig. 3]). The spatial arrangement can affect drop patterns, but the Pattern Simulation Model presently does not incorporate a mechanism for handling this variable, although it may be possible with future refinements. "Static Testing Information Checklist and Data Sheet" (appendix B) is a guide to assist in gathering various tank and gating system data, including general tank dimensions and geometry.

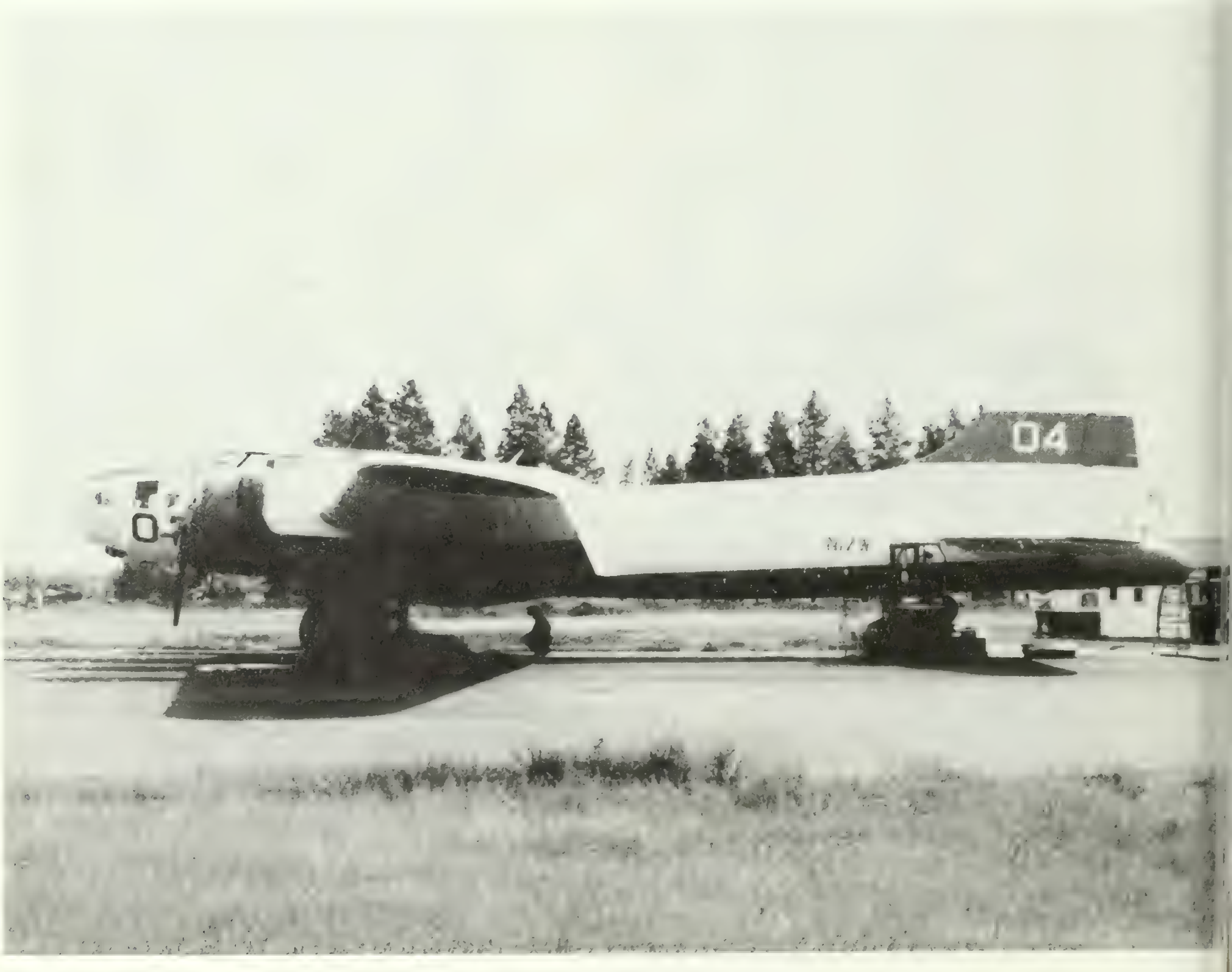


Figure 2.—Raising the tail of a B-17 to establish a "near-flight attitude" for static testing.

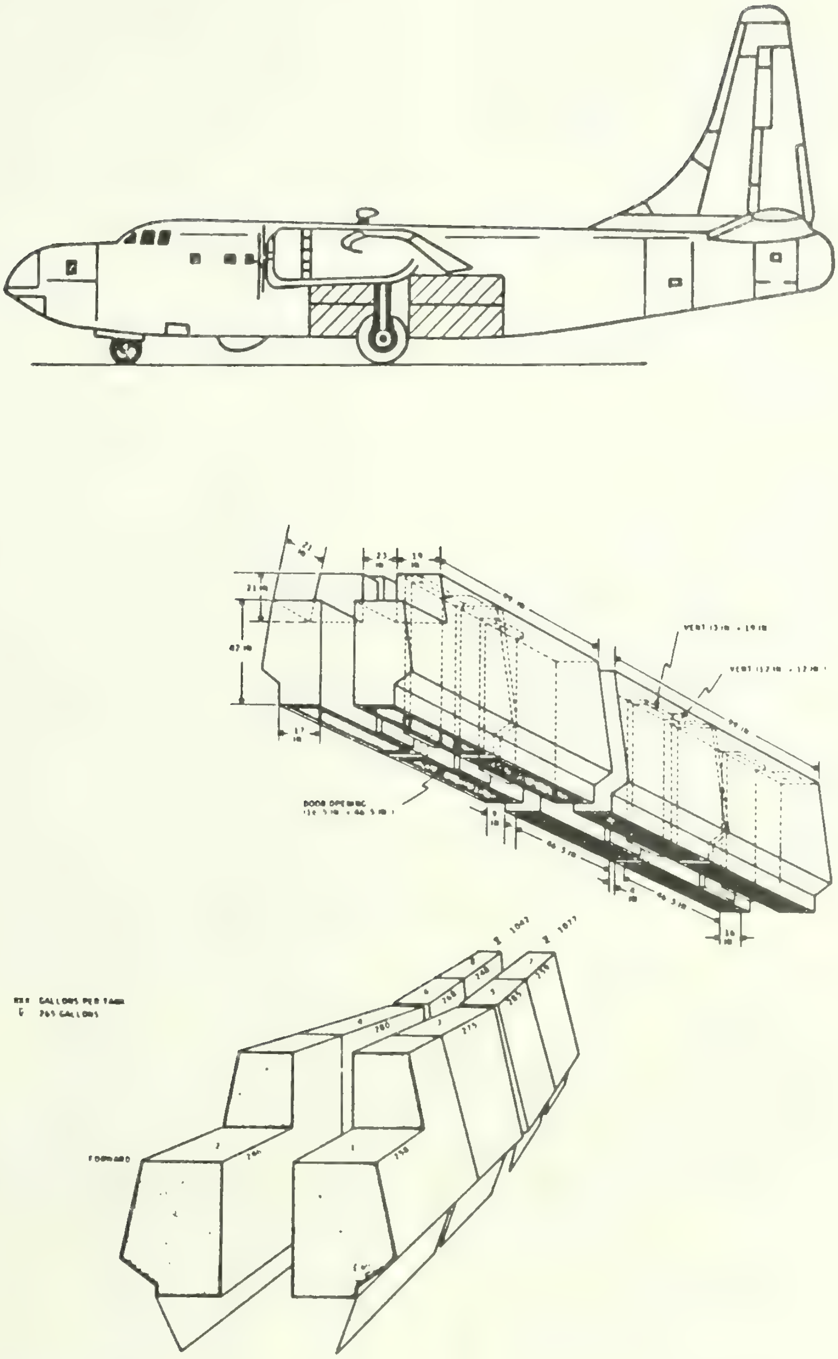


Figure 3.—Dimensions, volumes, and spatial arrangement of compartments of Hawkins and Powers tanked PB4Y2 airtanker.

Vent access should be measured and examined to determine: (1) the door-opening area to vent area ratios for each individual compartment, (2) situations where vent access routes may be shared by two or more compartments, reducing the available venting when multiple releases are made, and (3) if shared vent access is blocked by water when compartments are full.

Door travel should be checked by appropriate means to detect the variations in rates or angles. All doors should be opened in all possible drop sequences (singles, doubles, etc.) with and without water and with and without engine(s) running to determine: (1) the normal door opening sequences, (2) if all doors are opening and closing properly, (3) the door angles when fully open for all possible drop configurations, and (4) if differences in door opening times and angles exist.

Numerous factors can influence the time required for an individual door to open and the angle of opening. If doors do not open at a constant rate, then the opening areas as a function of time may not be linear. Some factors that may cause different door opening rates or angles on a tank and gate system are: (1) weight of and/or lubrication by water or retardant, (2) differences in the diameter and length of hydraulic lines serving each door, (3) insufficient accumulator, pump, or hydraulic line capacity for the number of compartments released simultaneously or in quick sequence, and (4) variable aircraft power source (that is, door opening system power is supplied by hydraulic pressure produced by aircraft engine pumps or hydraulic or pneumatic pumps are powered by aircraft batteries.) These differences are important in establishing a procedure that will assure door opening rates are the same in-flight as under nonflight static test conditions. The differences can usually be prevented by running an aircraft engine or engines or by using an adequate ground power unit. (Consideration of this factor should always be a part of conducting static tests.)

Determining the static test matrix

As previously mentioned, it is usually not necessary to perform complete static tests on every compartment of a tank and gate system. If compartments have similar geometries, door area, opening rates, and venting, the flow rates will not be significantly different. The problem, however, is to identify the situations where minor to major differences result in different performance and actual flow rate measurements become necessary.

Preparing a table of tank compartment characteristics will help to identify which compartments will require flow rate measurements. In all cases, it is necessary to quantify the door opening time and angle for each compartment and drop combination or sequence. Table 1 provides a description of various tank characteristics prepared in order to plan a static test matrix. Data as provided in table 1 can then be used to determine which compartments will represent other compartments with similar performance. When two or more compartments are chosen for testing, they should be in separate groups of multiple-compartment releases. The procedure can be illustrated using the Hawkins and Powers tank in a Super PB4Y2 described in table 1 (data from the Airtanker Performance Guide).

The apparent differences are compartment geometry, door opening times, and volume. Either compartment 1 or 2 should be tested because of the different geometry (there may be complications caused by loading, fill gages, access for placing instruments, etc., that can dictate choosing other compartments for testing). The average volume of compartments 3 through 8 is 271 gallons (1 026 liters); therefore, compartment 6 could be representative for this volume. Compartment 6 has a 1.4 sec door-opening time that could be representative for that parameter. Door sequences are: SINGLES - 1, 7, 3, 5, 2, 8, 4, 6; DOUBLES - 1 and 7, 3 and 5, 2 and 8, 4 and 6; and FOURS - 1, 3, 5, 7 and 2, 4, 6, 8. Therefore, compartments 6 and 1 apparently could represent all variables of different compartments.

Table 1.—PB4Y2 tank and gate system physical description and characteristics

Compartment	Door size	Compartment dimension	Door opening Times	Door opening Angles	Head height	Vent area	Vent ratio (door to vent area)	Metered volume[1]	Other
	Inches *L × W*	*Inches* *L × W × H*	*Seconds*	*Degrees*	*Inches*	*(Ft^2)*		*Gallons*	
1	46.5 × 16.5	50 × 19 × 63	1.5	68	52	1.27	4.4:1	258	Notch in front
2	46.5 × 16.5	50 × 19 × 63	1.8	68	52	1.28	4.4:1	246	Notch in front
3	46.5 × 16.5	50 × 19 × 63	1.7	68	52	1.38	4.4:1	275	
4	46.5 × 16.5	50 × 19 × 63	1.5	68	52	1.36	4.4:1	278	
5	46.5 × 16.5	50 × 19 × 63	1.5	68	52	1.38	4.4:1	285	
6	46.5 × 16.5	50 × 19 × 63	1.4	68	52	1.35	4.4:1	268	
7	46.5 × 16.5	50 × 19 × 63	1.5	68	52	1.35	4.4:1	259	
8	46.5 × 16.5	50 × 19 × 63	1.3	68	52	1.36	4.4:1	261	

[1] Variations in volume were caused by differences in tank configurations and slight differences in the location of the fill-level indicator switches.

Data Acquisition

Requirements

The data collected for calculating the necessary inputs o the pattern simulation program (PATSIM) include: fluid evel versus time, door-open angle versus time, internal ank pressure versus time, tank geometry (tank dimenions), door geometry, tank volume, and starting and nding positions of the float and doors. For all airtankers ested so far, the time required to open the doors and vacuate tanks has varied between 0.2 sec and nearly 5 ec. In order to accurately define the data, the readability f the time base should be within 2.0 percent of the total ime required for the event. Door-opening angle measurenents should be accurate to 1 degree, starting and endng fluid levels to one-eighth inch (3.2 mm) and pressure o 0.1 psi (70.3 kg/m²). Measurements of tank and door eometry to one-eighth inch (3.2 mm) and tank volume netered to within 5 gallons (18.9 liters) have proven dequate.

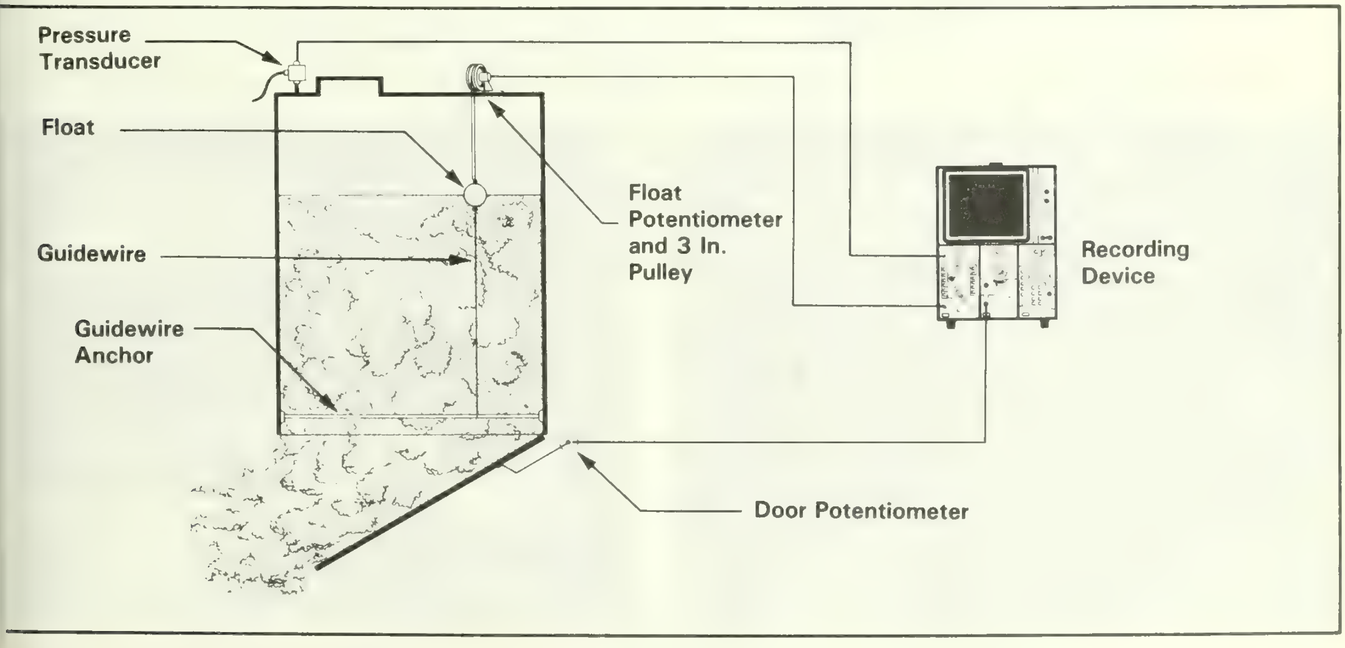
Methods

Three of the data measurements (fluid level, door open ngle, and internal tank pressure) are recorded against me by using a time base recorder. High-speed strip hart recorders, tape recorders, oscilloscopes with amera, and electronic data acquisition systems have all een used. Any recording device should have at least six hannels of input in order to provide measurements on ore than one compartment during each separate reease. The fluid level measurement is made using a float, orizontally stabilized by a guidewire, that rides on the urface of the fluid as it exits the compartment. The float is connected to a linear output potentiometer by a cord and pully arrangement (fig. 4), and the change in voltage is recorded as the float follows the dropping fluid surface. Since the voltage change is proportional to the distance traveled, the position of the float (or fluid level) at any given time can be calculated by using the measurements of float starting and ending positions. The mass of the cord and pulley arrangement must be kept as small as possible to avoid inertial effects.

Door-opening rate measurements are made with a potentiometer that is directly connected to an actuating arm that rides in a bracket taped to the door. Pressure measurements are made using a commercially available transducer that produces a DC signal proportional to pressure. The transducer is mounted at a location on the tank free of influence from other pressure sources, such as air drafts from the vent.

The full door-open angle is used primarily as a parameter to compare geometrically similar compartments at the start of testing. If "door open" times are the same for geometrically identical compartments, flow rates will be the same, therefore, only one of the identical compartments need be tested. Door times are also compared for the same compartment when different drop configurations are tested. (That is, compare the door times for a single compartment drop with times for a salvo drop. If they are the same, flow rates for these configurations should be identical.) When replicate drops have different flow rates, an examination of the associated door times may explain the difference.

Metering water into the tank assures the proper water level for a given load size at the start of testing. Once this level has been marked, each subsequent filling



igure 4.—Schematic of instrumentation.

should be within one-eighth inch (3.2 mm) of the mark for flow-rate accuracy.

Pressure measurements are made to identify drops when inadequate venting causes the dropping upper surface of the fluid to slow or stop and to incorrectly represent flow out of the tank. When the negative pressure is high enough, the dropping upper surface of the fluid is totally stopped while fluid continues to flow from the bottom of the tank (fig. 5). In this case, flow rate must be synthesized. (A method for synthesizing was developed by Honeywell Corporation [Swanson and others 1975] and is explained in detail.)

Data Processing

Data from the recording device or devices are digitized (unnecessary if an electronic data reduction system is used) by using an electronic system (fig. 6) and are stored on magnetic tape for reduction by using a desk top microcomputer. For most tests, about 30 digitized points are sufficient to define individual data traces. The points are chosen so that there is a relatively higher density of points over sharply curved portions of the trace. The digitized data are converted to volume discharged from the tank at a given time, flow rate, door opening area, door open angle, and tank internal pressure.

Since the door and float transducers produce linear voltage changes corresponding to float position and door-open angle, the door angle or float position at any given time may be calculated by:

$$\frac{F}{T} R = P$$

where F = total float travel (inches/centimeters), or maximum door-open angle (degree).
T = total trace displacement (in recorder units).
R = recorder trace displacement at time t.
P = float position or door-open angle at time t.

The pressure transducer is factory calibrated; therefore, actual pressure is found by applying a calibration constant.

To convert the position of the float in the compartme to volume discharged, an algorithm is derived, based on compartment geometry, that yields the volume remainin in the compartment at any float position. The compartment is divided into sections based on its geometry, an these sections are summed for the complete algorithm (fig. 7). The triangular ends are added to or subtracted from the rectangular portion for each section.

$$(W_i \times L_i \times D_i \times C) \pm 1/2\,(WT_i \times L_i \times D_i \times C)$$

(If both sides have triangular areas, the second term (1/2 $WT_i \times L_i \times D_i \times C$) is doubled.)

where WT_i = width of the base of the triangular portion in section i.

If θ_i = the angle between the rectangular and the triangular portion $WT_i = D_i \tan\theta$

$$\text{Volume} = W_i \times L_i \times D_i \times C \pm 1/2\,(D_i^2 \times L_i \times \tan\theta \times C$$

or for any float position Dt_i

$$\text{Volume} = Dt_i\,(W_i \times L_i \pm Dt_i^2\,\frac{(L_i \times \tan\theta \times C)}{2}$$

$$\text{Volume} = Dt_i\left[(W_i \times L_i \times C) \pm (Dt_i\,\frac{(L_i \times \tan\theta \times C)}{2})\right]$$

An example for Central Air Service DC-7 tanker 110 is give in appendix C.

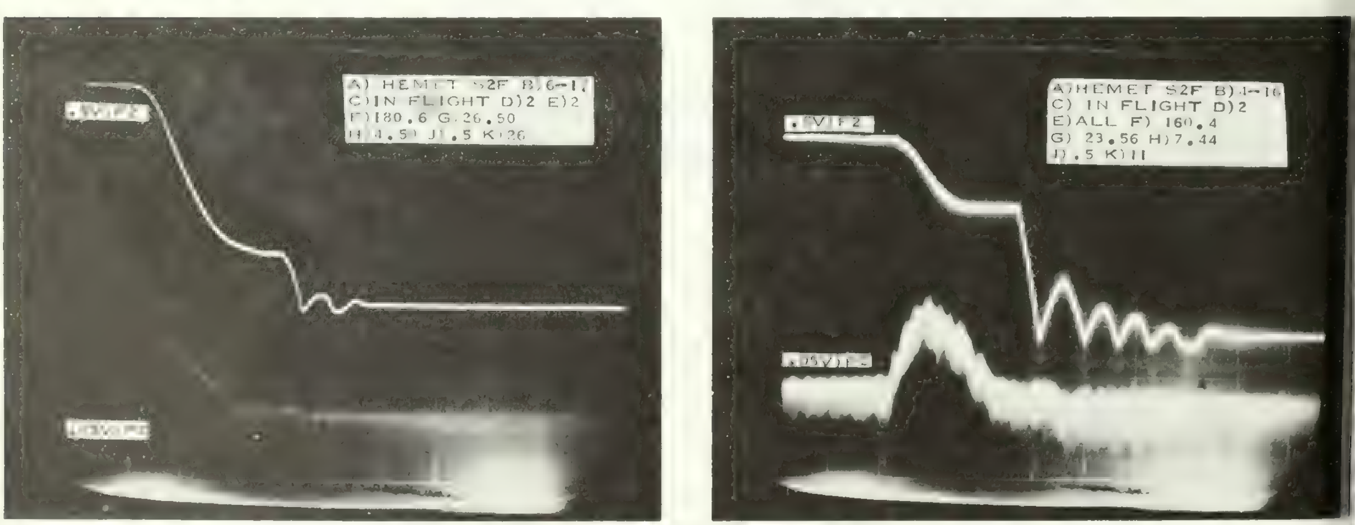
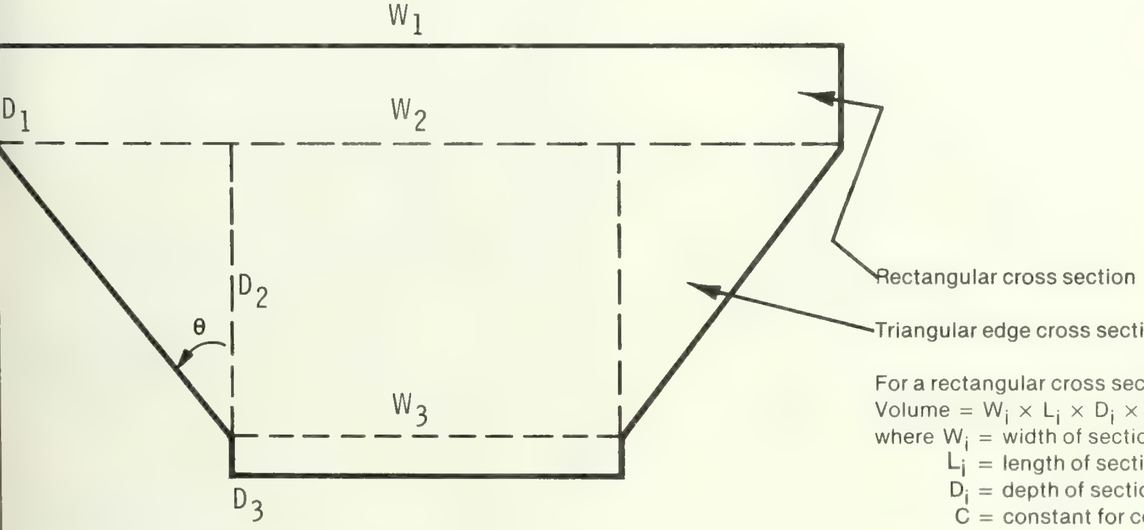


Figure 5.—Oscilloscope traces of the static test of an undervented tank. The single-compartment drop (left) and four-compartment drop (right) share the same venting. The four-compartment drop requires four times as much air, generating much greater negative pressures.

Figure 6.—Digitizing a polaroid photo of a static test oscilloscope trace.



For a rectangular cross section
Volume = $W_i \times L_i \times D_i \times C$
where W_i = width of section i
L_i = length of section i
D_i = depth of section i
C = constant for conversion to gallons

Volume in section i at any float position Dt_i
$V = Dt_i \times (W_i \times L_i \times C)$

gure 7.--Cross section of tank showing measurements
r volume-flow-level calculations.

Pattern Simulation

The main input to simulate a drop pattern using the PATSIM program is a table of volumes discharged versus time for the drop configuration being tested. Other inputs include drop height, drop speed, total volume dropped, retardant type (waterlike or gum-thickened), and the number of compartments dropped. For each PATSIM run, several different drop heights, airspeeds, etc., may be input to produce a set of simulated patterns covering a matrix of drop configurations. The details of operating PATSIM are published in reports (Swanson and others 1975, 1977) on the development of user guidelines for selected retardant aircraft. An instruction manual for utilizing user guides has been developed (Swanson and others 1976) and various "airtanker performance guides" have been prepared.[2]

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1955. Operation Firestop Prog. Rep. No. 9, Aerial Firefighting. USDA For Serv., Operation Firestop, 13 p. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif

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[2] Airtanker performance guides that have been prepared are on file and are available from the Northern Forest Fire Laboratory, Drawer G, Missoula, MT 59806.

APPENDIX A
INTERAGENCY AIRTANKER BOARD MANDATORY CRITERIA FOR NEW TANK AND GATING SYSTEMS

GENERAL

a. **Requirement:**
All tank systems shall not leak when loaded with water to a volume equivalent to the volume of retardant at the maximum certified retardant load. Following initial loading, the tank system shall be capable of sitting loaded as described above for a minimum of 1 week without leaking more than 3-1/2 gal (1/2 gal/24 h).
Procedure:
Load tank to certified amount using approved meter or weighing system. Determine the leakage occurring over a 14-h period (usually this will be overnight). The leakage volume for the 14-h period shall not exceed 0.3 gal.

b. **Requirement:**
All tanks must be equipped with an independently controlled and operated emergency dump system enabling the pilot to drop his complete load in less than 6 sec. No one major malfunction can render both the operating and emergency system inoperative. The primary dump switch must be positioned within easy reach of the pilot and copilot while strapped in their respective seats.
Procedure:
The emergency dump system must be operative when activated using the primary emergency dump switch(es) as described above.

c. **Requirement:**
All tanks shall have the capability of being offloaded through standard 3-inch Kamlock or equal couplers. Upon offloading, the amount of retardant remaining in the tank shall be less than 100 gal.
Procedure:
The operator must demonstrate the offload capability by connecting a 3-inch diameter hose and offload water from the tank.

d. **Requirement:**
All tank doors must be closable in flight.
Procedure:
Doors will be operative under static conditions. Flight tests will be required only if there is reason to question the operative ability of the door system during flight.

e. **Requirement:**
All retardant tanks shall be capable of being filled in conformity with the certified retardant load through 3-inch diameter single or dual Kamlock fittings, on either side of the aircraft or from the tail, at an average fill rate of no less than 500 gal/min. There should be sufficient crossflows so that the retardant will be level in all compartments within 30 sec after the pump is stopped. No compartment should fill faster than others such that retardant overflows from the tank (other than level indicator holes) before the certified volume is reached.
Procedure:
Tanks will be filled to the certified limit at 500 gal/minute and checked for even fill levels in each tank compartment.

f. **Requirement:**
Compartments sequenced individually in the normal drop configuration shall be constructed so as to eliminate leakage from one compartment to the other when one of the compartments has been evacuated.
Procedure:
All compartments will be filled to the level for a maximum certified load. Individual compartments will be manually activated in their normal sequence, checking each of the evacuated compartments for leaks from adjoining tanks. Leakage from adjoining tanks producing a combined flow of greater than 1 gal/min will constitute leakage.

g. **Requirement:**
Opening of the doors shall be through primary switches or a mechanism located on the control yoke or throttle/trim quadrant.
Procedure:
The activating switches will be checked visually as the tank and gate system is operated for static test drops.

II. VENTING

a. **Requirement:**
Vents shall be constructed so as no retardant leakage or slosh-over will occur during taxiing or takeoff.
Procedure:
A visual check and measurements will be made of vent construction, and the height of the retardant in a full tank will be checked for distance below vent outlets. If clearance or vent door construction is questionable, the aircraft will be taxied when loaded at the maximum certified load and observations for slosh-over or leakage made.

b. **Requirement:**
The vent area for any compartment or tank shall be such that when the retardant is released from any given compartment or combination of compartments, resulting negative pressures do not create a "coke-bottling" effect causing nonuniform and turbulent flow. A door area to vent area for any compartment or drop combination employed shall not be greater than 10:1 or shall show that in flight negative pressure does not exceed 0.25 lb/in^2.
Procedure:
Negative pressure will be checked with a pressure transducer during static test drops. Door opening and vent areas will be measured and the vent to door area ratio calculated.

III. INTERVALOMETER

Requirement:

Sequencing of all doors shall be done with an intervalometer capable of sequencing doors at intervals continuously variable. (Sequencing single or 2, 4, 6, 8 compartment combinations.) Reproducibility and accuracy shall be within ±0.1 seconds.

Procedure:

All door or drop combinations possible with the existing system will be monitored during static tests. Reproducibility and accuracy of timers will be checked with an oscilloscope, recorder, or other calibrated timing device.

IV. COMPARTMENT SIZE

Requirement:

1. Individual compartments shall not be less than 200 gal in size.
2. Individual compartments shall not be larger than 600 gal in size unless the gating system allows for reproducible control of the retardant flow rate of the > 600 gal by another method such as a pilot selectable dual door opening rate or a trail door (door of smaller size providing a lower flow rate).

Procedure:

Compartment capacity will be accurately metered while the airtanker is parked in a normal loading attitude. Existing marked fill levels will be checked and new ones permanently marked outside and inside the tanks when possible.

V. MULTIPLE COMPARTMENT DROPS

Requirement:

For drop combinations where more than one drop is made simultaneously, the rules given below shall be followed unless the drop configuration results in a weight distribution which causes the center of gravity to be outside the acceptable flight envelope.

1. When two or more compartments are dropped simultaneously (nonsalvo) and a choice of dropping forward and aft compartments, versus side-by-side compartments, is possible, the forward-aft combinations shall be employed (fig. 8).
2. Forward and aft compartments dropped simultaneously shall be in line with one another (fig. 8).
3. Side-by-side compartments dropped simultaneously shall be oriented in a manner to minimize separation (fig. 8).

Procedure:

All compartment drop combinations will be checked visually during static test drops.

VI. FLOW RATE

Requirement:

The flow rate of retardant from a compartment or compartments is the primary parameter controlling the ground distribution pattern. The required retardant concentration on the ground varies between 0.5 and 6+ gal/100 ft² depending on the fuel, weather, fire characteristics, etc. The concentration adequate for most fires and conditions is between 1 and 4 gal/100 ft².

The average flow rate for each load size/drop combination will be within a specified flow rate range. The acceptable range defined by minimum and maximum flow rates will be determined from the following equations, except for continuous flow trail systems where the minimum acceptable average flow has been set at 50 gal/sec. The acceptable flow rate range for selected sizes is given in table 2.

$$\text{Minimum average flow rate (gal/sec)} = \frac{DS}{2.03}$$

$$\text{Maximum average flow rate (gal/sec)} = \frac{DS}{0.42939 + 0.0000299039DS}$$

where DS = drop size in gallons.

Procedure:

Flow rates will be measured by monitoring floats which follow the top surface of the water when tank doors are opened. Floats will be monitored for all normal drop combinations, and flow rates will be calculated using a computer programed algorithm which combines float travel distance and time with tank geometry.

VII. DOORS

Requirement:

The door size, shape, and opening speed are all parameters which can influence the retardant flow rate from a tank. Many combinations of these parameters may provide acceptable flow rates as specified in item VI. The most desirable combination, however, should minimize the fluid frontal area, not significantly deflect the fluid, while providing this flow rate. Thus, generally a long, narrow tank versus a square tank, with a fast-opening door, will be preferable.

The door, when fully opened, does not restrict or deflect the flow of retardant from the tank. When multiple parallel doors exist, they should be hinged open inward so that all retardant will be deflected toward the center line of the tank. This will prevent simultaneous compartment drops from being deflected in opposite directions.

Procedure:

Door-opening rates will be monitored using a potentiometer that is fastened to the tank and in line with the door hinge. A wiper arm makes contact with the door and is connected to the shaft of the potentiometer. Door angle versus time is transmitted to a recorder placed nearby. The measured door-opening times are used as indicators in identifying problems in flow rate (item VI) and sequencing (intervalometer, item III).

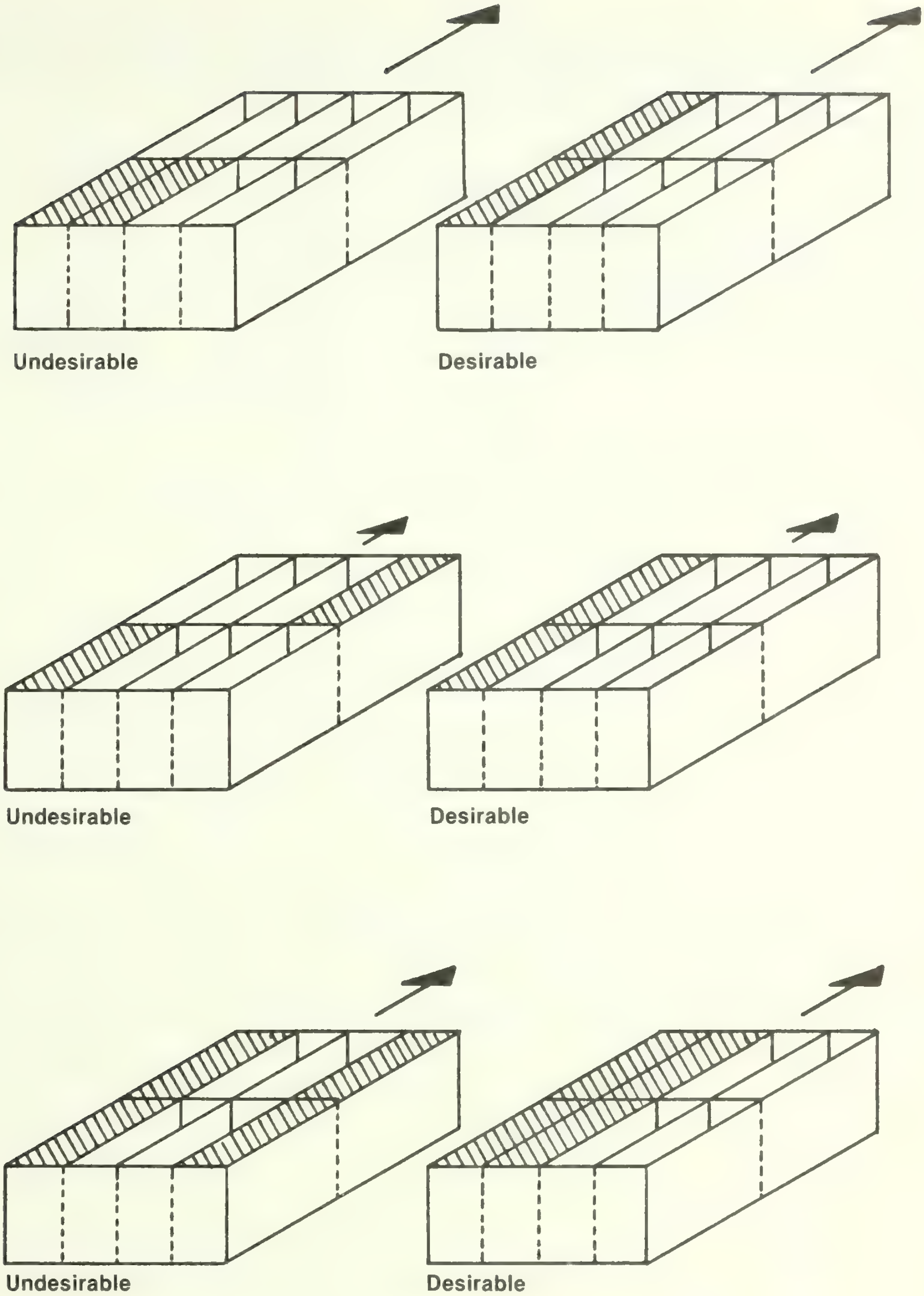


Figure 8.--Rules of configuration for multiple compartment drops.

Deflection of fluid exiting the tank will be visually checked and recommendations will be made for correcting if the deflection is caused by door-opening times or structural configuration that can be corrected by minor modifications.

VIII. TANK FILL-GAGE

Requirement:

A positive-level gage or indicator shall be provided that shows when each compartment is filled to the certified load limit, or when each compartment is at predetermined partial load points if reduced loads are used. The gage or indicator shall be readily visible to the loading crew at the loading points and the tank capacity of each loading level clearly marked.

Procedure:

Fill-level gages are checked by metering accurate volumes of water while the aircraft is in its normal filling attitude. Permanent markers placed to indicate the certified load limit levels will be evaluated.

Table 2.—Acceptable flow-rate range for selected drop sizes.

Drop size	Average flow rate	
Gallons	*Minimum gal/sec*	*Maximum gal/sec*
200	98	445
250	123	550
300	148	653
350	172	754
500	246	1,044
1000	493	1,892
1200	591	2,189
1500	739	2,595
2000	985	3,187
2400	1,182	3,598
2800	1,379	3,962
3000	1,478	4,129

APPENDIX B — STATIC TESTING INFORMATION CHECKLIST AND DATA SHEET

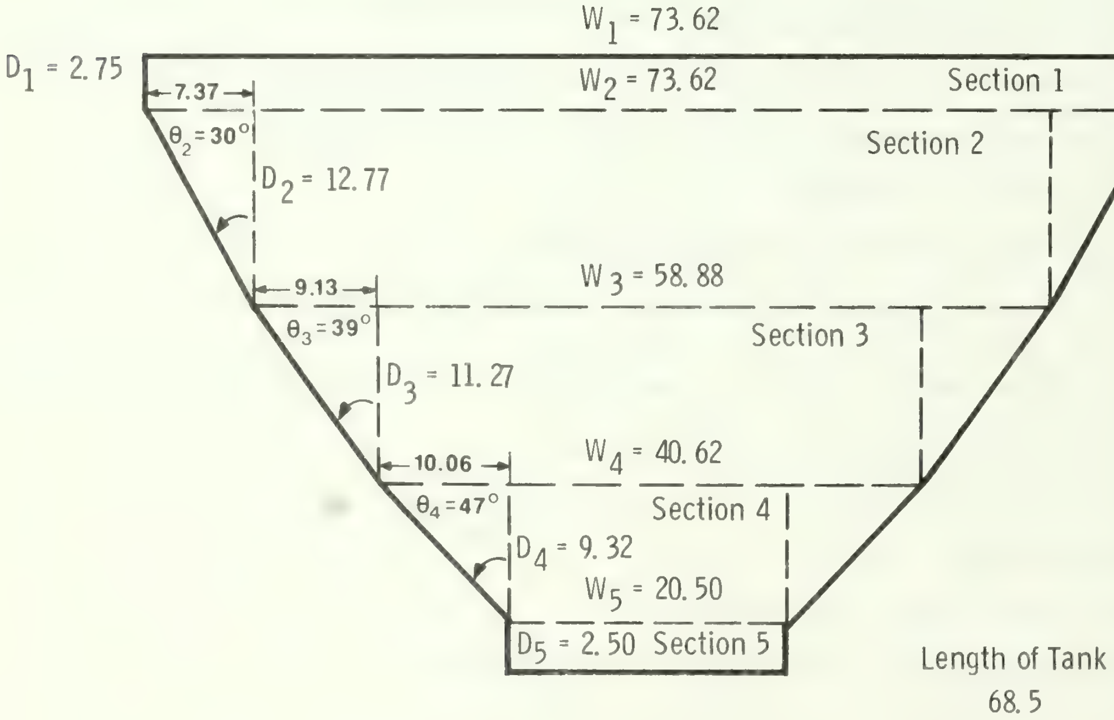
1. Operator ____
2. Designer and/or Fabricator ____
3. Aircraft Type ____
4. Airtanker ID: Tanker #____________; N____________; S/N____________
5. FAA Certified Maximum ____________________ Lbs.; ____________________ Gal.
6. Contract Volume(s) ________; ________; ________; ________; ________; ________
7. ID Number and Volume of each compartment: ________; ________; ________; ________; ________; ________; ________; ________
8. Compartment Combinations for Multiple and Sequence Drops:
   Doubles ________; Triples ________; Fours ________; Sixes ________; Eights ________;
   Other ________; ________; ________;
   Trail Sequence ____
9. Describe Door System: *
10. Describe Tank: * Sketch and label all dimensions so that a scale line drawing may be made (side and end views). This information will be used to calculate algorithm.
11. Describe impediments to flow: * (should include interior tank bracing, door operating mechanism, baffles, etc.)
12. Describe Venting: * (include placement in tank and outside of aircraft dimensions, etc.)
13. Diagram compartment Numbering Order: *
14. Diagram and describe intervalometer or door triggering system: *
15. Diagram and describe Fill System: * (include location, crossflow arrangement, downloading capability, valves, dimensions, etc.)
16. Describe any differences between static and in-flight configuration that may affect testing and compensate for them.
17. Check for leaks: (interior or exterior)
18. Describe emergency dump system: *
19. Describe any special features of system:
20. Photograph airtanker, tanks and operating systems.
21. Fill airtanker using accurate meter and mark tank at volumes to be tested.
22. Fill levels and location of level to be tested: ________; ________; ________; ________; ________; ________; ________;
23. Record test matrix to be used:
24. For each test drop record
    a. Position of float in compartment.
        1. From top of compartment.
        2. From side and end of compartment.
        3. Distance from bottom of compartment to position of float at end of drop.
    b. Total vertical float travel.
    c. Drop configuration.
    d. Volume.
    e. Compartments tested.

*Provide measurements and/or drawing.

APPENDIX C
DATA ANALYSIS AND VOLUME DISCHARGE ALGORITHM FOR CENTRAL AIR SERVICES DC-7 (TANKER 110)

The compartment dimensions and float travel measured during static testing of Central Air Services DC-7 tanker #110 were used to design an algorithm to calculate quantity discharged from the tank on a time basis for input to the PATSIM program. Door opening measurements are converted from analog data to angular units (degrees) as a function of time. Pressure measurements are converted to pounds/in² using a calibration constant for the individual transducer and recorded over the time base.

(Example Tank Cross Section)



The sections are:

Section 1, top of tank to 2.75 down.
Section 2, 2.75 down to 15.52 down.
Section 3, 15.52 down to 26.79 down.
Section 4, 26.79 down to 36.11 down.
Section 5, 36.11 down to 38.61
(bottom of tank).

Applying the method in figure 7.

Volume of Section 1 = $2.75 \times 68.5 \times 73.62 \times C$

($C = 4.33 \times 10^{-3}$ to convert inches to gallons or 16.38×10^{-3} to convert to liters.)

Volume for any float position i in Section 1:

$= D1_i (73.62 \times 68.5)$

where $D1_i$ is the distance the float has fallen within section i.

Volume $= 21.84\ D1_i$

For Section 2 with a triangular cross section

Volume = volume of rectangular portion − volume of triangular sections.

Applying the method in figure 7.

$\text{Volume}_2 = D2_i (73.62 \times 68.5 \times C) - 68.5\ ((D2_i)^2 \times \text{Tan } 30°)\ C$

$\text{Volume}_2 = D2_i (21.84 - 0.17119 D2_i)$

Similarly:

Section 3, $\text{Volume}_3 = D3_i (17.725 - .2401\ D3_i)$

Section 4, $\text{Volume}_4 = D4_i (11.864 - .318\ D4_i)$

Section 5, $\text{Volume}_5 = 6.079\ D5_i$

An example of the analog data converted to appropriate units is given in table 3. Discharge data in this form are input to PATSIM to predict ground patterns for selected drop conditions. The flow rate is also calculated and is included in the technical data section of the airtanker performance guides.

able 3.—Performance data for a single compartment release from Central Air Service DC-7 (Tanker #110)

Time	Distance above tank bottom	Volume discharged	Flow rate	Door open angle	Pressure	Section[1]
Sec	*Inches*	*Gallons*	*Gal/sec*	*Degrees*	*Lb/in²*	
0	35.8	0	0	0	0	2
0.05	35.4	10	190	2.1	-0.01	
.10	34.8	21	213	4.8	-.02	
.15	34.1	36	237	8.5	-.04	
.20	33.2	55	275	13.5	-.07	
.25	31.5	90	360	20.5	-.09	
.30	29.4	130	434	27.9	-.10	
.35	27.2	172	483	35.3	-.11	
.40	25.0	213	532	42.2	-.12	
.45	22.6	253	562	48.3	-.12	3
.50	20.3	292	585	53.2	-.12	
.55	17.8	330	600	54.7	-.11	
.60	15.5	363	605	68.6	-.11	
.65	13.2	392	603	76	-.10	
.70	10.9	420	599	80	-.10	4
.75	8.7	442	590		-.09	
.80	6.7	460	575		-.09	
.85						
.90						

[1] Fill level is below section 1. Mechanical restrictions required mounting the float end point above section 5.

Blakely, Aylmer D., Charles W. George, and Gregg M. Johnson.
1982. Static testing to evaluate airtanker delivery performance. USDA For. Serv. Gen. Tech. Rep. INT-78, 17 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

The USDA Forest Service in cooperation with Honeywell Corporation has developed a series of Airtanker Performance Guides to provide predictions of fire retardant ground distribution patterns from drop heights up to 500 feet when dropped from a number of different airtankers. The performance guides were produced using a Honeywell-developed simulation program and static test data for each specific tank and gating system. This report describes a method for collecting static test data and the analysis used in the development of the airtanker performance guide. This is done so the performance of any existing airtanker can be compared to the performance of any other specific airtankers that have been static tested.

KEYWORDS: airtankers, performance, ground distribution pattern, simulation models, tank and gating system, static testing, procedure tank geometry, venting, door opening, design, criteria

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FIRE ECOLOGY OF LOLO NATIONAL FOREST HABITAT TYPES

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Kathleen M. Davis
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USDA Forest Service General Technical Report INT-79
Intermountain Forest and Range Experiment Station
Forest Service, U.S. Department of Agriculture

USDA Forest Service
General Technical Report INT-79
May 1980

FIRE ECOLOGY OF LOLO NATIONAL FOREST HABITAT TYPES

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INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Forest Service
U.S. Department of Agriculture
Ogden, Utah 84401

FOREWORD

Fire management actions will support resource management objectives when land managers have a knowledge of fire relationships and the skill to use this knowledge during the planning process. The result of this "front-end" analysis will be the development of presuppression, suppression, and fire use criteria and actions that actively further management direction. This paper provides fire ecology knowledge that managers need for appropriate resource decisions.

This fire ecology paper by Davis, Clayton, and Fischer will significantly assist Lolo National Forest personnel to establish the following fire-related management guidance:

1. Develop fire information data base.
    a. Determine fire history.
    b. Determine man's impacts on the biological system.
    c. Determine fire ecology relationships.
    d. Determine fuel situation by such specifics as cover type and habitat type.

2. Process and interpret data base (fire behavior potential and management implications).

3. Integrate fire information with habitat type groups.

4. Formulate land management alternatives.

5. Formulate fire management strategies for land management alternatives.

6. Simulate fire and economic consequences of each fire management strategy.

7. Select a management alternative and its fire management strategy.

8. Prepare operational fire management plans (for example, fire use plan, preattack plan, fuel management plan, fire management area plan, wilderness fire managemen plan).

The habitat type groups used in this publication are helpful descriptors that can be used to connect fire/ecosystem relationships to the planning process and to implemen fire management prescriptions. The habitat type groups are recognizable parts of ecosystems that are ecologically distinct in terms of topographic features, soils, vegetation, fuels, and fire behavior potential. The groups can be classified and mapped; thus, they can serve as a ready index for many kinds of information.

Not only does the ecosystem stratification account for the important intraunit attributes, but it also portrays interactions among units. The patterning of habitat type groups in space (each with inherent biological, physical, and climatic features) guides a logical process in formulating management decisions.

We are indebted to Davis, Clayton, and Fischer for providing relevant information to land managers in a format that is especially helpful for program and project plannin

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Lolo National Forest

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RESEARCH SUMMARY

This report summarizes available information on fire as an ecological factor for forest habitat types occurring on the Lolo National Forest.

The Lolo National Forest habitat types are grouped into 10 Fire Groups based primarily on fire's role in forest succession.

For each Fire Group, information is presented on (1) the relationship of major tree species to fire, (2) forest fuels, (3) the natural role of fire, (4) fire and plant succession, and (5) relative fire management considerations.

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INTRODUCTION

URPOSE

This report is a summary of available fire ecology and management information that plies to habitat types of the Lolo National Forest. Primary attention is given to e tree component. The undergrowth is treated by plant form, except in a few cases ere certain species are discussed.

Habitat types are arranged into 10 "Fire Groups" based on the response of the tree ecies to fire and the roles these tree species take during successional stages. The ception is Fire Group Zero, which is a collection of miscellaneous vegetation types.

The reader should be cautioned that (as in all cases where an attempt has been de to impose order on the heterogeneity of nature) the Fire Groups defined in this port include a number of borderline cases. Differences in fire behavior and in ccessional patterns often depend on very small local changes in fuel, temperature, isture, sunlight, topography, and seed availability. Thus it would be possible for ands that key to the same habitat type to fall into different Fire Groups. A certain liance is placed on the judgment of the land manager in evaluating the local conditions any particular site. The groups defined in this report are intended as a general ide, not a definitive treatment.

The information contained in this report is geared to the composition of habitat pes on the Lolo National Forest. Many of these habitats occur throughout western ntana; therefore, the information may be extrapolated with care.

ORMAT

Habitat Types — Phase and Ecoclass Code

The Fire Groups are defined with reference to *Forest Habitat Types of Montana* fister and others 1977) and the "ecoclass" silvicultural grouping of On and Losensky 977). The habitat types occurring in the Lolo National Forest are listed in pendix A.

Habitat types are designated in the standard format of "Series/Type - Phase", in ich "series" designates the potential climax dominant tree, "type" designates a finitive undergrowth species, and "phase" provides a further subdivision where needed.

The ecoclass codes take the form "XX - # - ###" (appendix B). The first letter, presenting the dominant plant lifeform, is always a "C," which stands for "conifer." e second letter is an abbreviated symbol representing the dominant potential climax ecies, such as "S" for subalpine fir. The single-digit number represents the silvi- ltural group (1 through 8), and the last three digits are data processing codes sociated with Pfister's habitat types.

Relationship of Major Tree Species to Fire

This section of each chapter is devoted to a discussion of the characteristics of ch important tree species in the Fire Group with regard to its resistance or suscep- bility to fire and its role as a successional component of forest communities. Parti- lar attention is given to special adaptations to fire, such as corky bark, serotinous nes, or seeds that require mineral soil for germination.

Forest Fuels

In this section, we discuss the kind and amount of dead, woody material likely to be found on the forest floor. The discussion is based on fuel inventory data (Brown 1974) from two different sources. The prime source is a photo series for appraising natural fuels in wild stands on the Lolo National Forest and vicinity. The other source is timber inventory (Stage I) fuel data from western Montana national forests.

It is important to remember that these discussions are about dead, woody material on the forest floor. Live fuel and standing dead fuel are treated casually, if at all, because fuel data on this material were not collected as part of the inventories mentioned above.

Cover type names used in this section are those suggested by the Society of America Foresters (1954).

Role of Fire

Information on the important trees and forest fuel is integrated with available fir history studies to describe the role of fire in shaping the vegetative composition of a particular Fire Group. This section is mainly a literature review covering succession and fire in the appropriate habitat types.

Fire intensity is described as light, moderate, and severe. Light fires are low intensity surface fires which burn through surface fuels and remove a portion of the litter and duff. Moderate fires are surface fires of higher intensity which burn through shrubs and other understory vegetation. Such fires are capable of torching overstory trees. The greatest intensity and potential for damage is experienced with severe fires, which often kill the overstory and recycle the vegetation to the secondary successional stages. More concise descriptions of fire intensity are not possible because the literature provides little basis for more precision.

Succession Diagram

The succession diagram and associated text represent a simplified, synthetic overview of fire's role in succession for all habitats of each Fire Group. For clarity, no literature references are given in this section since it is intended to serve as a graphic and uncomplicated presentation of the material covered earlier in the chapter.

The accompanying diagram represents a visual summary of the effects that fires of varying intensity can have on the habitat types. Secondary succession begins with the lowest seral form, but the diagram can be used from any stage of stand development. In habitat types with aggressive seral conifers, the shrub/herb stage is short lived. Numerous facts which may influence the vegetation on the landscape have been neglected in order to emphasize the potential influences of fire and fire suppression.

The conifer species are symbolized in order to simplify the diagrams. The symbols are defined as follows:

Pinus ponderosa, ponderosa pine (PIPO)
Pseudotsuga menziesii, Douglas-fir (PSME)
Pinus contorta, lodgepole pine (PICO)
Larix occidentalis, western larch (LACO)
Picea engelmannii, Engelmann spruce (PICEA)
Abies lasiocarpa, subalpine fir (ABLA)
Tsuga mertensiana, mountain hemlock (TSME)

Larix lyallii, alpine larch (LALY)
Pinus albicaulis, whitebark pine (PIAL)
Abies grandis, grand fir (ABGR)
Thuja plicata, western redcedar (THPL)
Tsuga heterophylla, western hemlock (TSHE)

Fire Management Considerations

The purpose of this section is to suggest how the preceding information can be used develop fire management plans that support land and resource management objectives. e discussion is intended to be suggestive, not dogmatic. Each individual manager is a much better position than are the authors to relate the information presented in is report to a particular management situation.

HE FIRE GROUPS

The forest habitat types of Montana (Pfister and others 1977) have been assembled to 12 Fire Groups which are defined as follows:

Fire Group Zero: A heterogeneous collection of special habitats. On the Lolo National Forest these sites exist as scree, forested rock, meadow, grassy bald, and alder glade.

Fire Group One: Dry limber pine habitat types. These occur most often east of the Continental Divide in Montana. This group is not represented on the Lolo National Forest.

Fire Group Two: Warm, dry ponderosa pine habitat types. This group consists of open ponderosa pine stands with a predominantly grass undergrowth. These sites may exist as fire-maintained grasslands, and do not support Douglas-fir, except as "accidental" individuals.

Fire Group Three: Warm, moist ponderosa pine habitat types. These sites occur in eastern Montana. Fire Group Three is not represented on the Lolo.

Fire Group Four: Warm, dry Douglas-fir habitat types. These are areas that exist in nature as fire-maintained ponderosa pine stands that develop Douglas-fir regeneration beneath the pine in the absence of disturbance.

Fire Group Five: Cool, dry Douglas-fir habitat types. Douglas-fir is often the only conifer that occurs on these sites. In the absence of fire, dense Douglas-fir sapling understories may develop.

Fire Group Six: Moist Douglas-fir habitat types. Group Six habitat types will support substantial amounts of Douglas-fir even when subjected to periodic fire.

Fire Group Seven: Cool habitat types usually dominated by lodgepole pine. This group includes stands in which fire maintains lodgepole pine as a dominant seral as well as those in which it is a persistent dominant species.

Fire Group Eight: Dry, lower subalpine habitat types. This is primarily an eastern Montana group although it is represented on the Lolo.

Fire Group Nine: Moist, lower subalpine habitat types. Group Nine is a collection of lower subalpine habitats in which fires are infrequent, but severe, with long-lasting effects.

Fire Group Ten: Cold, moist upper subalpine and timberline habitat types. Group Ten is a collection of high-elevation habitats in which fires are infrequent. Small area fires are common because of the fuel situation. Severe fires have long-term effects.

Fire Group Eleven: Warm, moist grand fir, western redcedar, and western hemlock habitat types. These are moist habitats in which fires are infrequent and often severe.

Habitat types representing ten of the twelve Fire Groups defined above occur on the Lolo National Forest. Fire Groups One and Three habitats are absent. Fire Group Five and Eight habitats occupy only a small acreage. Consequently, Fire Groups One and Three are not discussed in this report and Fire Groups Five and Eight are discussed together with Groups Six and Nine, respectively.

FIRE GROUP ZERO

MISCELLANEOUS SPECIAL HABITATS

The following special habitats account for 9 percent of the land area on the Lolo National Forest.

Scree

Scree (talus or rock debris) describes slopes covered with loose rock fragments (Fairbridge 1968). Often scree slopes are treeless, but those with finer rock can support open forest cover with sparse undergrowth. Species composition is extremely variable with ponderosa pine, Douglas-fir, western larch, spruce, alpine larch, and subalpine fir all occasionally associated with scree (Pfister and others 1977).

The lack of fuel makes scree slopes almost unburnable. Individual trees or clumps of vegetation can ignite, but fire spread is limited by discontinuous vegetation. Windswept crown fires could carry fire through this habitat, but, in actuality, scree slopes rarely burn.

Because of the lack of soil development, low site production, and low site moisture revegetation of burned scree slopes would be slow.

Forested Rock

Forested rock is a rock face or rock outcrop that supports some conifer (and possibly hardwood) trees with sparse undergrowth. Vegetation may grow in clumps or be scattered over the rock formation. Species growing here include ponderosa pine, Douglas-fir, juniper, and alder.

Surface fire poses little threat to the plant cover because the rock component limits fire spread and may even act as a fire break. Intense fires in adjoining, contiguous forest may burn across the forested rock as spot fires or windswept crown fires.

Revegetation is slow on forested rock because of the lack of soil development, low site productivity, and low site moisture.

Meadow

Meadow vegetation in this context is herbaceous matter growing on sites that are subirrigated part or all of the growing season (On and Losensky 1977). Consequently, meadows are difficult to burn. In fact, their succulent vegetation may act as firebreaks to moderately intense fires; however, if these habitats dry out late in the growing season, they become more flammable.

Fire may reduce meadow vegetation to ground level, but species that are capable of resprouting will be little damaged. Naturally occurring fire has had a role in maintaining meadows. Fire suppression has allowed conifers to invade many of these habitats.

Grassy Bald

Grass covered openings within continuous forest comprises only 0.4 percent of the Lolo National Forest.

If the balds are green, they can act as firebreaks. If the grass is cured, then windswept fire can quickly burn across the opening into heavier fuels within the forest. In this manner, the readily ignitable, fine herbaceous fuels hamper fire suppression by augmenting fire spread.

This habitat is relatively unharmed by fire because the herbaceous vegetation resprouts readily. In fact, grassy balds would probably benefit from the nutrient increase from ash and removal of decadent foliage. Fire may also be a factor that keeps conifer regeneration from invading the openings.

Alder Glade

An alder glade is an opening in the forest vegetated by *Alnus*. The site is characteristically a mesic location (north slope, wet meadow, ravine, seepage) that is too wet for associated conifers.

Alder is moderately fire resistant because of its nonflammable bark and nonresinous leaves. Resistance is further enhanced when *Alnus* grows in thickets because the duff is cool and moist and undergrowth is sparse. In addition, its occurrence on mesic sites reduces vulnerability to fire.

Alder glades probably burn infrequently, but intensely. Fire promotes dense stands of *Alnus* because it stimulates resprouting. As with aspen, alder stands may be maintained by fire.

Fire Management Considerations

Fire managers can take advantage of the presence of Group Zero habitats when developing preattack plans and when delineating fire management areas. These areas can also serve as anchor points for fuel breaks or firebreaks.

FIRE GROUP TWO

WARM, DRY PONDEROSA PINE HABITAT TYPES

Habitat type - phase (Pfister and others 1977)	Ecoclass code (On and Losensky 1977)
Pinus ponderosa/Agropyron spicatum h.t. (PIPO/AGSP), ponderosa pine/bluebunch wheatgrass.	CP-1-130
Pinus ponderosa/Festuca idahoensis h.t.-*Festuca idahoensis* phase (PIPO/FEID-FEID), ponderosa pine/Idaho fescue-Idaho fescue phase.	CP-1-141
Pinus ponderosa/Festuca idahoensis h.t.-*Festuca scabrella* phase (PIPO/FEID-FESC), ponderosa pine/Idaho fescue-rough fescue phase.	CP-1-142
Pinus ponderosa/Purshia tridentata h.t.-*Agropyron spicatum* phase (PIPO/PUTR-AGSP), ponderosa pine/bitterbrush-bluebunch wheatgrass phase.	CP-1-161
Pinus ponderosa/Purshia tridentata h.t.-*Festuca idahoensis* phase (PIPO/PUTR-FEID), ponderosa pine/bitterbrush-Idaho fescue phase.	CP-1-162
Pinus ponderosa/Symphoricarpos albus h.t.-*Symphoricarpos albus* phase (PIPO/SYAL-SYAL), ponderosa pine/snowberry-snowberry phase.	CP-1-171

This group consists of open-grown ponderosa pine stands with predominantly grass undergrowth. These are habitats which may exist as fire-maintained grassland and which will support juniper and Douglas-fir as "accidental" individuals. In some habitat types, juniper may be a minor climax species. Sites are typically hot, dry, south- and west-facing slopes at low elevations, forming the lower timberline in the area. Slopes are often steep with poorly developed soils. During summer months, moisture stress is a critical factor for plant growth. Group Two habitat types cover only 0.1 percent of the Lolo National Forest.

Relationship of Major Tree Species to Fire

Juniperus scopulorum

Young juniper trees are easily killed by fire primarily because of their small size, thin bark, and compact crown. Fire has long been recognized as a means to contr juniper since it does not resprout. Often young trees are killed just by scorching the crown and stem.

As juniper ages, the bark thickens and the crown develops a bushy, open habit. A intense fire can kill or severely damage such a tree, but the same tree can survive a lesser surface fire. Low, spreading branches may provide a route for fire to enter th crown thereby increasing the potential for damage. Often large junipers can survive a number of fires (four to six).

The different effects of fire on young and old juniper trees are largely a function of the site. The species commonly occupies dry, subhumid environments which support limited undergrowth. When surface fuels are sparse, fire damage is minimal.

In the Lolo National Forest, juniper and ponderosa pine are the only successfully reproducing conifers in the *Pinus ponderosa* climax series. Juniper occurs as an accidental or minor climax individual.

Pinus ponderosa

Ponderosa pine has many fire-resistant characteristics. Seedlings are able to withstand high temperatures, whether from a light surface fire or from the severe thermal stress inherent in becoming established on hot, dry exposures. Early development of insulative bark and the tendency for meristems to be shielded by enclosing needles and thick bud scales contribute to this temperature resistance.

Propagation of fire into the crown is unusual because of four factors. First, the thick bark is relatively unburnable and does not easily carry fire up the bole or support residual burning. Resin accumulations, however, can make the bark more flammable. Second, the tendency of ponderosa pine to self-prune lower branches keeps the foliage separated from burning surface fuels. Third, the open, loosely arranged foliage does not lend itself to combustion or the propagation of flames. Fourth, the foliage has a high moisture content.

Seedling establishment is favored when fire removes the litter and exposes mineral soil. Fire resistance of the Group Two open, parklike stands is enhanced by variable light fuel quantities. Heavy accumulations of litter at the base of trunks increase the intensity and duration of fire, often resulting in a fire scar or "cat face." Flammable resin deposits around wounds make the tree susceptible to fire damage and usually cause an enlargement of the scar.

Forest Fuels

Fuel loads in Group Two stands tend to be rather light when compared to stands in other fire groups. Often, the most abundant surface fuel is nonwoody, dead, or curing grass. This is especially true for mature, open-grown stands of ponderosa pine. Downed woody fuels in such stands usually consist of widely scattered, large trees (deadfalls) and concentrations of needles, twigs, branchwood, bark flakes, and cones near the base of individual trees. Fuel loads in such stands may be less than 1 ton/acre (0.2 kg/m^2).

Fuel loads in dense pole and small sawtimber stands may be much higher than in the older open-type stands. Figure 1 shows a range of loadings that can exist in these young stands. Stand 24 (fig. 1A) shows a 137-year-old interior ponderosa pine stand on a *Pinus ponderosa/Festuca idahoensis* h.t.-*Festuca idahoensis* phase (PIPO/FEID-FEID), ponderosa pine/Idaho fescue-Idaho fescue phase with a fuel load of 1.1 tons/acre (0.3 kg/m^2). The fuels in this stand are primarily pine needles. Stand 72 (fig. 1B) is an 80-year-old interior ponderosa pine stand on a *Pinus ponderosa/Symphoricarpos albus* h.t.-*Symphoricarpos albus* phase (PIPO/SYAL-SYAL), ponderosa pine/snowberry-snowberry phase. Total fuel load is 16.5 tons/acre (3.7 kg/m^2), most of which is the result of natural thinning caused by competition for light and moisture. A comparison of fuel oadings by size class for these two stands is given in table 1.

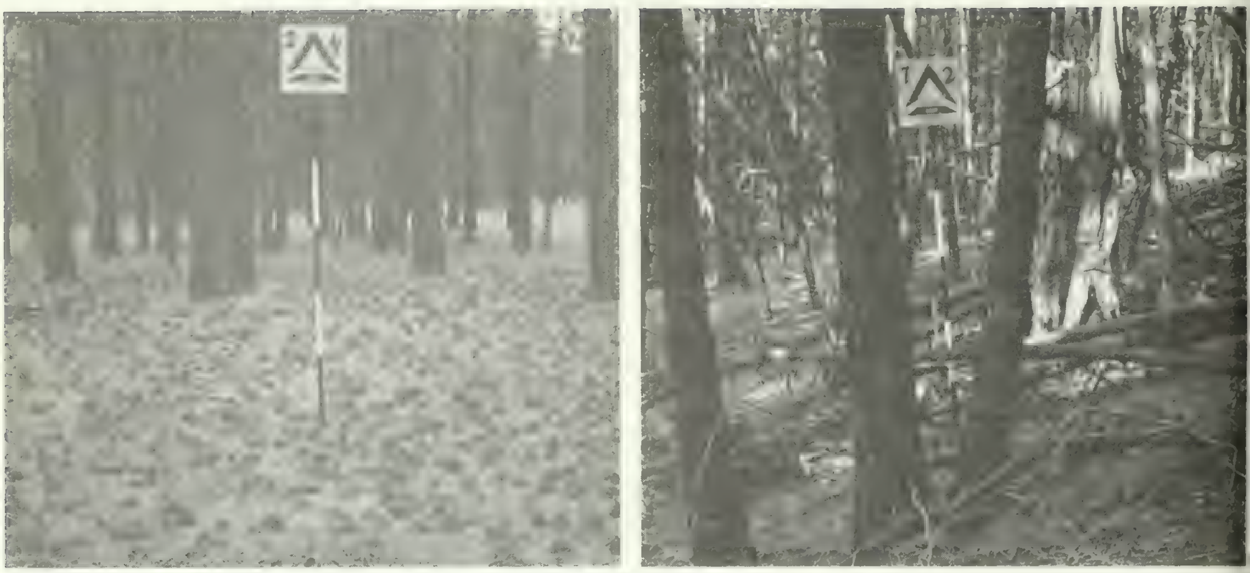


Figure 1.--A range of Group Two fuel loads: A. Stand 24 is a 137-year-old ponderosa pine stand on a *Pinus ponderosa/Festuca idahoensis* h.t.-*Festuca idahoensis* phase; B. Stand 72 is an 80-year-old ponderosa pine stand on a *Pinus ponderosa/Symphoricarpo* *albus* h.t.-*Symphoricarpos albus* phase. See table 1 for fuel load by size class and total fuel load.

Table 1.--*Fuel loading by size class for two Fire Group Two stands (fig. 1)*

Stand number	Age	Size class (inches)						Total
		0-1/4	1/4-1	1-3	3-6	6-10	10-20	
	Years	- - - - - - - - - - - - - *Tons/acre* - - - - - - - - - - - - - - - - -						
24	137	0.01	0.60	0.40	0.10	0	0	1.10
72	80	0.14	2.20	4.40	5.34	2.30	2.10	16.48

Role of Fire

The PIPO habitat types are too dry to support the more mesic tree species except as accidental individuals. Consequently, fire's role is limited to three functions:

1. Maintaining grasslands. Grassland areas capable of supporting ponderosa pine may remain treeless through frequent burning.
2. Maintaining open pine stands. The open condition is perpetuated by periodic fires which reduce the number of seedlings and thin stands. Fire burning in the heavi accumulation of needle litter beneath mature trees eliminates regeneration. Also, litter and dense undergrowth covering mineral soil prevents seedling establishment.

3. Preparing a seedbed by exposing mineral soil, reducing competing vegetation, and increasing nutrient availability. Depending on the seed crop, weather, and continuity of the seedbed, regeneration may appear as dense stands, separated thickets, or scattered individuals. Periodic fires can create uneven-aged stands comprised of various even-aged groups. Severe fires will result in a predominantly even-aged stand.

Natural fire frequencies in forests adjacent to grasslands are fairly high, according to numerous fire history studies conducted in the ponderosa pine forest types throughout the western States. These studies have shown fire to be a frequent event, occurring at intervals of from 5 to 25 years in most locations. In Group Two habitat types of the Bitterroot National Forest, Arno (1976) reported a range of 2 to 20 years and a mean fire-free interval of 10 years for fires occurring somewhere in sizeable stands (100 to 200 acres [40 to 81 hectares]). Fire history investigators caution that these figures are conservative estimates of the mean fire-free intervals. Intervening light ground fires could have effects on stand development without leaving scars on trees.

The effects of fire suppression during the 20th century on some Lolo National Forest Group Two sites have been confounded by the rocky, dry nature, low site productivity, and the influence of grazing. In more productive sites, the absence of fire has resulted in overstocking and increased fuels. Natural regeneration on Group Two sites in the Lolo National Forest is quite slow, and, in many cases, fire suppression has caused very little fuel buildup. In fact, on gravely south slopes, fuels are light and variable both vertically and horizontally in spite of 50 or more years without fire. Occasionally, thickets of moderate to heavy fuels do occur, but the surrounding sparse fuels and openstand structure reduce the hazard. Such areas may not be available to burn during some years simply because of a lack of fuel.

Generally, the herbaceous and shrub growth recover well after fire. Wildlife forage can be improved by burning through the elimination of old unpalatable vegetation and their replacement by nutrient-enriched regrowth. In the case of the *Pinus ponderosa/ Purshia tridentata* h.t. (PIPO/PUTR), ponderosa pine/bitterbrush, fire reduced or eliminated *Purshia tridentata* temporarily, but the plant quickly reestablished itself. With repeated burns, the undergrowth can go to grasses.

Succession Diagram

Figure 2 is a generalized succession diagram for Fire Group Two habitats. Repeated, frequent fires will maintain a predominantly herbaceous community by killing tree seedlings and favoring plants capable of root stock regeneration (fig. 2, No. 1). Grasses dominate the undergrowth, but other herbs and small shrubs may be present especially in *Pinus ponderosa/Symphoricarpos albus* h.t.'s (PIPO/SYAL), ponderosa pine/snowberry. Ponderosa seedlings may become established during an extended fire-free period or episodically following a seedbed preparing burn (fig. 2, No. 2). On dry sites, seedbed preparation may be less significant because litter cover is sparse and mineral soil is already exposed. If undisturbed, the seedlings will develop into saplings then pole-sized trees; however, a light-to-moderate fire during the seedling/sapling stage will return the site to a grass-dominated community (fig. 2, No. 3) or thin the regeneration (fig. 2, No. 4) by killing the younger and smaller pines. Local fuel situations are very important to survival of seedlings and saplings.

Over time, the pole-sized trees mature. Periodic fires during this time create an open, parklike stand (fig. 2, No. 5). Light ground fires keep the stand from becoming overcrowded because the accumulated litter and undergrowth burn hotly enough to kill most of the regeneration. Severe fires are not likely to occur in stands of pole-sized or mature trees.

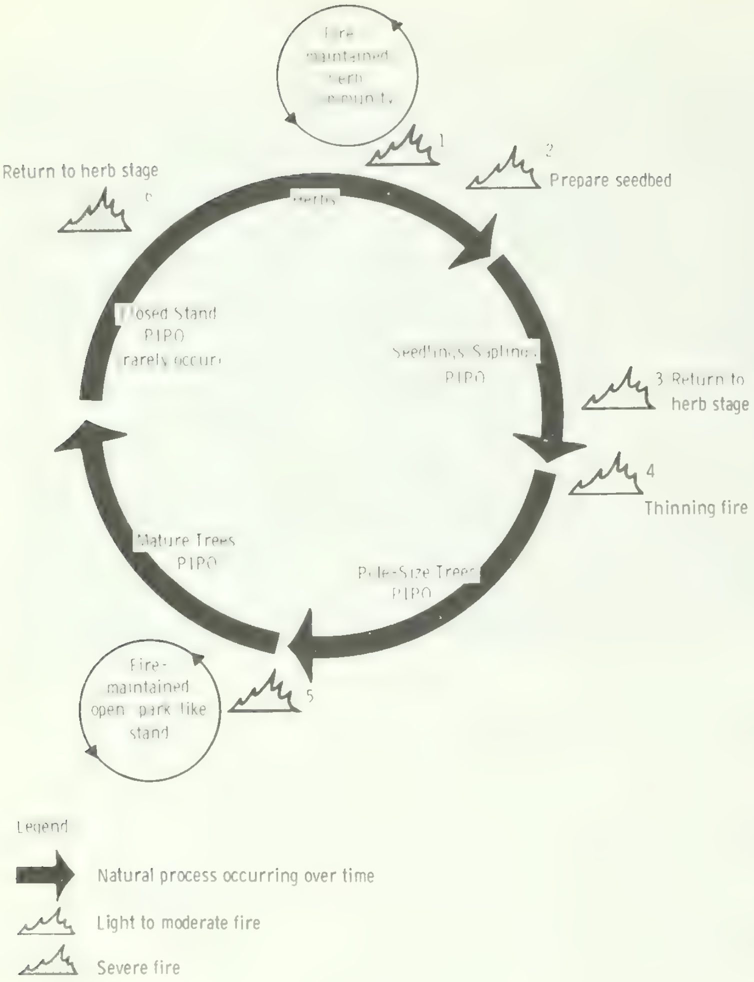


Figure 2.--Forest succession in Fire Group Two: Ponderosa pine climax series habitat types.

Long periods of successful fire suppression could, in theory, produce overstocking of these sites due to the maturation of unthinned saplings; however, other site factors are so limiting that this condition is rarely observed in the Lolo National Forest. The formation of overstocked stands and their elimination by stand-destroying fires (fig. 2, No. 6) is probably not a common, natural event in these habitat types.

Fire Management Considerations

Fire management activities should be geared to resource management objectives and stand conditions. This is especially important when using fire (Fischer 1978). Fire management activities in Group Two stands are most often designed to reduce wildfire hazard, regenerate trees, and improve forage production.

Wildfire Hazard Reduction

Prescribed fire can be used to reduce accumulated dead grass, needles, and woody debris in stands of pole-sized and larger trees, thereby lessening the chance of tree killing wildfires. Similarly, slash hazard can be reduced by broadcast burning after cutting. In order to maintain a low level of flammability in Group Two stands, fire must be applied periodically whenever sufficient fuel accumulates to carry fire. Where heavy fuels exist prior to the initial entry with prescribed fire, it is often best to plan several burns in successive years rather than to risk the cambium kill and crown scorch often associated with a hot fire (see fire use considerations below).

Silviculture

Because seedling establishment is often difficult and growth is slow, fire should be excluded from areas while desirable ponderosa pine regeneration is present. If regeneration is absent, but desired, prescribed fire can be used to prepare seedbeds. Prescribed fire is particularly useful for removing the duff layer on *Pinus ponderosa/ Symphoricarpos albus* h.t.'s (PIPO/SYAL), ponderosa pine/snowberry.

Range and Wildlife Habitat Management

Forage production for livestock and big game can be enhanced by proper application of fire on Group Two habitat types. On *Pinus ponderosa/Agropyron spicatum* h.t.'s (PIPO/AGSP), ponderosa pine/bluebunch wheatgrass and *Pinus ponderosa/Festuca idahoensis* h.t.'s (PIPO/FEID), ponderosa pine/Idaho fescue, grasses can be rejuvenated by removing dead grass and releasing stored nutrients. Fire will often result in an increased production of nutrient-rich forbs on these habitat types. On *Pinus ponderosa/Symphoricarpos albus* h.t.'s (PIPO/SYAL), ponderosa pine/snowberry, light surface fires will rejuvenate shrubs through fire-simulated sprouting and cause a temporary increase in grass and forb production. Fire may be difficult to apply on *Pinus ponderosa/Purshia tridentata* h.t.'s (PIPO/PUTR), ponderosa pine/bitterbrush where percent cover by plants is low and litter is sparse. Where it will carry, fire can be used to rejuvenate the undergrowth by killing decadent bitterbrush and thereby allowing new plants to invade the site. As a general rule, luxuriant growth of shrubs will not result from fire use on Group Two habitat types.

Fire Use Considerations

Care must be taken when burning in forest stands to prevent or minimize scorching the crowns of desired overstory trees. If heavy fuel accumulations or slash occur near the base of overstory trees lethal cambium heating must also be avoided.

Excessive crown scorch, cambium damage, or both can result in tree mortality, loss of vigor, and increased susceptibility to bark beetle attack.

For example, the relationship between crown defoliation and mortality caused by the western pine beetle (*Dendroctonus brevicomis*) in ponderosa pine has been generalized as follows (Stevens and Hall 1960):

Percent defoliation	Percent of trees killed by beetles
0-25	0-15
25-50	13-14
50-75	19-42
75-100	45-87

The season in which a fire occurs is an important factor influencing the occurrence, duration, and severity of beetle attack--should one occur--on fire-weakened trees. The result of crown scorching is usually more severe during the active growth period early in the summer than later when growth has slowed, terminal buds have formed, and a food reserve is being accumulated (Wagener 1955, 1961). Likewise, crown scorching that occurs in early spring, before or immediately after bud burst, often results in minimum damage to the tree.

Prescribed burning of understory vegetation and dead surface fuels can be carried out without serious threat of subsequent damage by bark beetles provided the overstory trees are not severely scorched by the fire. If accidental scorching does occur, and bark beetle activity is detected, prompt removal of the severely scorched trees will reduce the probability of subsequent damage to healthy green trees. If scorching occurs outside the active growth period, scorched trees may recover and regain lost vigor. This may take 3 years, but signs of recovery should be visible during the first growing season that follows scorching.

Another consideration concerns frequency of burning. The effects of repeated burning on a given site are not well defined for western Montana forests. Consequently, it seems prudent to gear the frequency of prescribed fire on a site to the wildfire frequencies that existed prior to organized fire suppression (see Arno 1976).

Another very important consideration concerns the need to retain a certain amount of woody material for maintenance of forest site quality. Current understanding of the relationships between organic matter and ectomycorrhizae in northern Rocky Mountains forest soils is based on recent work in western Montana (Harvey, Jurgensen, and Larsen 1976, 1979b; Harvey, Larsen, and Jurgensen 1976; Jurgensen, Larsen, and Harvey 1977; and Larsen, Jurgensen, and Harvey 1978).

Harvey, Larsen, and Jurgensen (1979a) offer the following general guidelines for wood management:

> Within the northern Rocky Mountains, the high productivity and rapid decay rates of warm-moist forests make them less sensitive to depletion than sites with low-to-moderate productivity. However, in specific instances, managing for certain types of old growth forest may retain aspects of decayed wood conservation, even on productive sites (Franklin and others 1979). Conversely, dry- or cold-site management should emphasize conservation of large woody materials within fuel limits that do not create unacceptable wildfire risk. Such woody materials should, where possible, be left in contact with the soil to create optimum conditions for decay.
>
> Where early access to mineral soil seedbeds is critical to reforestation, post-harvest slash treatments should be directed toward creating a mosaic of fuel dispersal. It would be advantageous to have both large woody residues and bare mineral surface scattered across the site; so seeds can germinate rapidly and seedlings have access to the nutrients, moisture, and ectomycorrhizal activity provided by decaying wood and humus. Size of both slash piles and windrows for prescribed burning should be dictated by minimum standards that will achieve adequate small fuel reduction. Soil disturbance should be minimal and not create continuous expanses of mineral surface.
>
> Management of wood on intermediate sites is less clear. Until more data are available, they should be treated as though they are at least moderately sensitive to reduction of soil wood.

Harvey, Jurgensen, and Larsen's preliminary estimates indicate that about 10 to 15 tons of 4-inch (10-cm) diameter or larger woody material should remain on the site following logging and burning. In addition, only as much mineral soil should be bared as is necessary to obtain desired stocking. The authors further suggest that amounts of organic matter in excess of the above requirements can be considered undesirable, especially on dry sites. Excess buildup of fuels can set the stage for high intensity wildfires that result in an extreme reduction of the soil's organic reserves.

Scattered large logs left on a site also retard soil movement and provide shade for young seedlings. Some species will not successfully regenerate without such shade.

A third reason for leaving a moderate amount of woody material of large diameter scattered over the forest floor is to assure a food source for woodpeckers, especially the pileated woodpecker (*Dryocopus pileatus*). Woodpeckers and other cavity-nesting birds also require snags, preferably scattered patches of snags, for nesting sites (McClelland and Frissell 1975; McClelland and others 1979). Fuel management programs should consider such needs.

FIRE GROUP FOUR

WARM, DRY DOUGLAS-FIR HABITAT TYPES
USUALLY FIRE-MAINTAINED PONDEROSA PINE STANDS

Habitat type - phase (Pfister and others 1977)	Ecoclass code (On and Losensky 1977)
Pseudotsuga menziesii/Agropyron spicatum h.t. (PSME/AGSP), Douglas-fir/bluebunch wheatgrass.	CD-1-210
Pseudotsuga menziesii/Festuca scabrella h.t. (PSME/FESC), Douglas-fir/rough fescue.	CD-1-230
Pseudotsuga menziesii/Physocarpus malvaceus h.t.-*Calamagrostis rubescens* phase (PSME/PHMA-CARU), Douglas-fir/ninebark-pinegrass.	CD-2-262
Pseudotsuga menziesii/Symphoricarpos albus h.t.-*Agropyron spicatum* phase (PSME/SYAL-AGSP), Douglas-fir/snowberry-bluebunch wheatgrass phase.	CD-1-311
Pseudotsuga menziesii/Calamagrostis rubescens h.t.-*Agropyron spicatum* phase (PSME/CARU-AGSP), Douglas-fir/pinegrass-bluebunch wheatgrass phase.	CD-1-321
Pseudotsuga menziesii/Calamagrostis rubescens h.t.-*Pinus ponderosa* phase (PSME/CARU-PIPO), Douglas-fir/pinegrass-ponderosa pine phase.	CD-2-324
Pseudotsuga menziesii/Spiraea betulifolia h.t. (PSME/SPBE), Douglas-fir/white spiraea.	CD-2-340

Group Four consists of Douglas-fir habitat types that exist in nature as fire-maintained ponderosa pine stands and develop Douglas-fir regeneration beneath the pine in the absence of disturbance. Douglas-fir may be present in seral stands, but pine will dominate. These habitat types are too droughty for other conifer species except those occurring as accidental individuals (appendix C). These stands are generally quite open, but dense stands or thickets can occur where fire has been excluded or where good seed years have followed fire. The understory is usually sparse because of lack of moisture and consists of herbs (mainly grasses) and occasional patches of ninebark and serviceberry. Group Four habitat types cover 10 percent of the Lolo National Forest.

Relationship of Major Tree Species to Fire

Juniperus scopulorum

Juniper has the same relation to fire in Group Four as it does in Group Two. The species occurs only in two habitat types as an accidental or minor climax tree (appendix C).

Pinus ponderosa

The major effect that fire has on ponderosa pine in this group is the elimination of competing species, particularly Douglas-fir. In this group of habitat types, ponderosa's fire-resistant characteristics give it a competitive advantage over Douglas-fir.

Pseudotsuga menziesii

Mature Douglas-fir is a fire-resistant tree; however, saplings are vulnerable to surface fires because of their thin bark, resin blisters, closely spaced inflammable needles, and thin bud scales. The moderately low and dense branching habit of saplings enables surface fires to be carried into the crown layer. Older trees develop a relatively unburnable, thick layer of insulative bark that provides protection against low-to-medium intensity fires. The development of "gum cracks" in the lower trunk that streak the bark with resin, can provide a mechanism for serious fire injury. Douglas-fir does occur in open-grown stands, but more often it grows in denser stands with continuous fuels underneath. As with ponderosa pine, heavy fuel accumulations at the base of the tree increase the probability of fire injury. Also, resin deposits usually enlarge old scars.

Douglas-fir regeneration is favored by fire, which reduces vegetation cover and exposes mineral soil so shallow taproots of seedlings can take hold. Also, the increase sunlight enhances rapid growth. On dry sites, too much exposure can retard conifer vegetation.

Forest Fuels

Fuel loads are heavier on the average than those found in Fire Group Two ponderosa pine stands, but lighter than those in most other groups. The average fuel load for the Group Four stands that were sampled was about 11 tons/acre (2.5 kg/m^2), with a range of from 2 to 30 tons/acre (0.5 to 6.7 kg/m^2). As a very general rule, fuel loads tend to increase with stand age as a result of accumulated downfall from insect and disease damage, blowdown, and natural thinning. Stands of the same age may have widely differen fuel loads, however. This is especially true in dense, young stands where heavy mortality from natural thinning can cause rapid fuel accumulation.

The different types of Group Four fuel situations likely to be encountered are shown in figure 3 and listed in table 2. All of these ponderosa pine stands are growing on a *Pseudotsuga menziesii/Physocarpos malvaceus* h.t.-*Calamagrotes rubescens* phase (PSME/PHMA-CARU), Douglas-fir/ninebark-pinegrass.

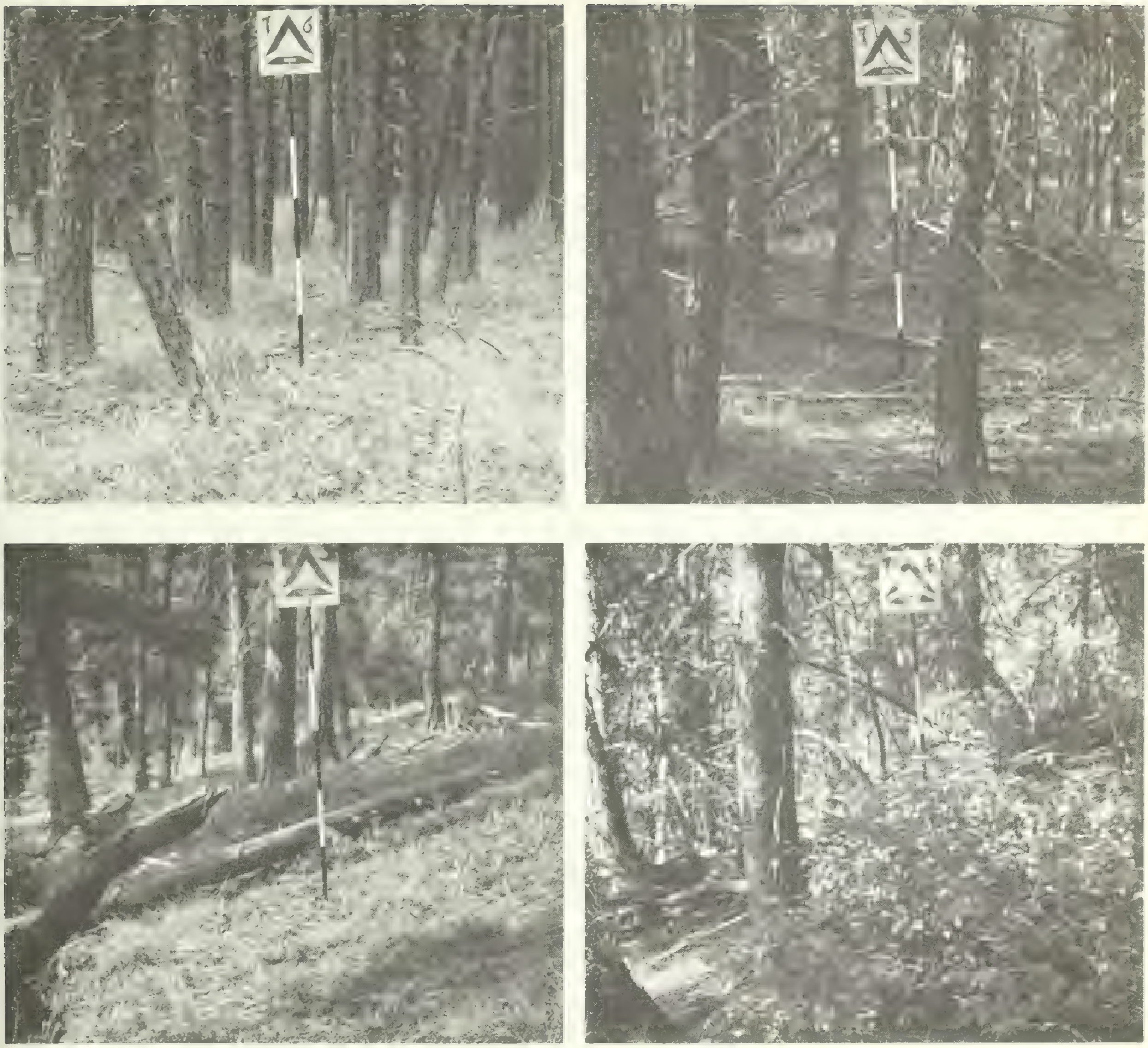


Figure 3.--Examples of Group Four fuel loads on a *Pseudotsuga menziesii/Physocarpus malvaceus* h.t.-*Calamagrostis rubescens* phase. Stand age, total fuel load, and fuel load by size class are given in table 2.

Table 2.--*Fuel loading by size class for four Fire Group Four stands (fig. 2)*

Stand number	Age	Size class (inches) 0-1/4	1/4-1	1-3	3-6	6-10	10-20	20+	Total
	Years	*Tons/acre*							
76	60	0.14	0.90	0.80	0.64	0.13	0	0	2.61
75	65	0.47	1.40	4.60	3.05	0.50	0.70	0	10.72
73	172	0.45	1.00	1.10	1.76	5.64	1.47	0	11.42
74	173	0.89	1.70	3.60	3.96	4.50	1.83	3.70	20.18

Stand 73 (fig 3) is a ponderosa pine stand that represents the average fuel load for Group Four stands. It has a load of 11.4 tons/acre (2.6 kg/m^2), most of which is the result of accumulated downfall of material larger than 3 inches (7.6 cm) in diameter (table 2).

The relationship between stand condition and fuel load is shown by stands 76 and 75 (fig 3). Both stands are 60-year-old ponderosa pine stands on a *Pseudotsuga menziesii/Physyocarpus malvaceus* h.t.-*Calamagrostis rubescens* phase. These stands are growing within one-half mile (0.8 km) of each other in the same drainage. Downfall from natural thinning has made the difference between a fuel load of 2.6 tons/acre (0.6 kg/m^2) in stand 76 and 10.7 tons/acre (2.4 kg/m^2) in stand 75 (table 2).

Sometimes the combined effect of moderate amounts of periodic deadfall and moderate amounts of natural downfall from natural thinning will result in a heavy fuel load. This situation is shown in stand 74 (fig. 3), a 173-year-old ponderosa pine stand with a 60-year-old Douglas-fir understory. The fuel load in this stand is 20.2 tons/acre (4.5 kg/m^2).

Role of Fire

Fire in the Douglas-fir climax series habitat types of Group Four maintains grasslands, opens up stands, and prepares seedbeds (see Group Two), but there are additional effects:

1. Frequent fires in seral pine stands can prevent the establishment of Douglas-fir creating a "fire climax." In this role, fire frequency largely determines the stand composition.
2. Following a prolonged fire-free period Douglas-fir regeneration becomes established beneath the canopy. A ground or surface fire that reaches a thicket of saplings and small poles can ascend into the overstory, killing or injuring adjacent mature trees through the vegetative "fuel ladder." Fuel ladders increase the potential destructiveness of a fire by providing access to the canopy. During periods of high fire danger, this can result in a stand-destroying crown fire.

Historic fire frequency in Group Four habitat types probably is not very different rom that of Group Two, that is, about 10 years beyween fires. Successful suppression f surface fires in open, fire-maintained ponderosa pine stands over the last few decades as altered the sites toward a severely overstocked and highly flammable condition hat has increased the fire potential.

Succession Diagram

The accompanying diagram (fig. 4) represents the effects of fire in Group Four. requent burning will maintain a shrub and herb community in which individual conifers ay be present (fig 4, No. 1). The exclusion of fire will permit the establishment nitially of ponderosa pine and then of Douglas-fir. Conifer seedlings also may become stablished following a burn (fig. 4, No. 2), but this effect of fire can be of minor mportance where seedling establishment is not hindered by ground cover. A light-to-oderate intensity fire during the seedling/sapling stage will recycle the vegetation o the shrub/herb stage (fig. 4, No. 3) or thin the conifers (fig. 4, No. 4) by killing he smaller and younger trees.

A stand of pole-size trees becomes established with time. A severe fire at this tage returns the stand to an earlier phase of development (fig. 4, No. 5). The ikelihood of a severe fire increases with suppression mortality and fuel ladders. aturally occurring, moderate intensity fires favor the establishment of young ponderosa ines rather than a pine/Douglas-fir mixture (fig. 4, No. 6). This is due to the greater ire tolerance of young pine and its superior ability to occupy burned sites. Subsequent ires will maintain an open, parklike ponderosa stand by thinning the understory and avoring ponderosa.

In the absence of fire, the mixed seedlings develop into a stand of mature trees, n which Douglas-fir will tend to replace the ponderosa pine if given sufficient time. round fires through the mixed stand will not harm mature specimens of either species, ut will tend to keep the stand open and discourage regeneration (fig. 4, No. 7). eriodic fires will tend to favor a pine understory.

Without fire, Douglas-fir regeneration quickly appears beneath the overstory and n time creates a fuel ladder situation that often precedes stand-destroying fires in hese types. High intensity fires in mature stands (fig. 4, No. 8) or climax Douglas-ir stands (fig. 4, No. 9) will revert the site to the earliest vegetation stage. A limax Douglas-fir forest is not likely to be achieved in this group because of the proonged fire-free period necessary for its development.

Fire Management Considerations

Fire management considerations and opportunities for Group Four stands involve azard reduction, seedbed preparation, control of species composition, safeguarding ecreation sites, improving wildlife habitat, and enhancing esthetic values.

Wildfire Hazard Reduction

In the absence of fire, hazardous fuel situations often develop in Group Four tands. Ablaze, the combination of dense Douglas-fir (or ponderosa pine) understories, ccumulated deadfall, decadent shrubs, and other accumulated litter and debris can roduce fires intense enough to scorch the crowns and kill the cambium of overstory rees. Although they were developed in western larch--Douglas-fir forests (fire Groups ive and Six), Norum's (1977) guidelines can be used to write fire prescriptions for afely reducing this hazard. Prescribed fire can also be used to reduce the hazard ssociated with logging slash resulting from clearcuts and partial cuts in Group Four tands. Most fire prescriptions can be writen so as to accomplish silvicultural, range, nd wildlife objectives as well as hazard reduction.

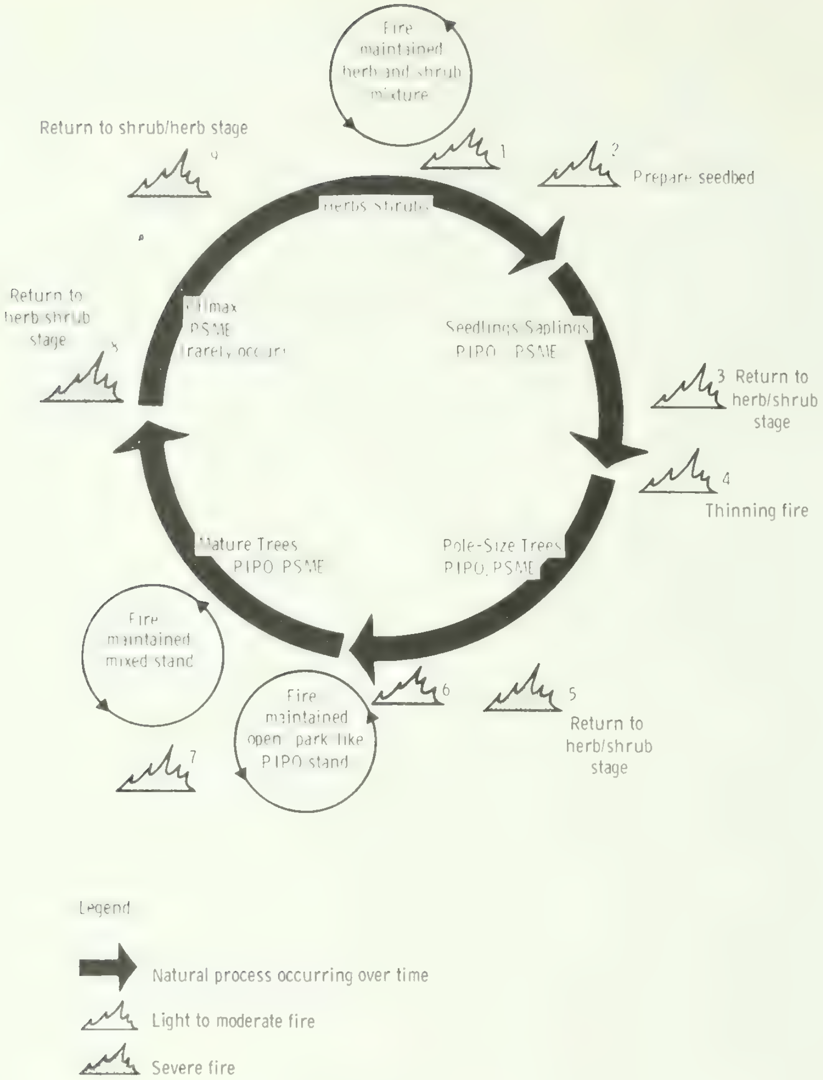

Fire maintained herb and shrub mixture
Return to shrub/herb stage
9
1
2
Prepare seedbed
Herbs Shrubs
Return to herb shrub stage
8
Climax PSME (rarely occurs)
Seedlings Saplings PIPO PSME
3 Return to herb/shrub stage
4 Thinning fire
Mature Trees PIPO PSME
Pole-Size Trees PIPO, PSME
Fire maintained mixed stand
Fire maintained open park like PIPO stand
6
5 Return to herb/shrub stage
7
Legend
Natural process occurring over time
Light to moderate fire
Severe fire

Figure 4.--Forest succession in Fire Group Four: fire-maintained ponderosa pine stands in Douglas-fir climax series habitat types.

More than one fire entry may be necessary to reduce hazard to an acceptable level in some stands. An example might be stands with a dense Douglas-fir understory that has been severely damaged by spruce budworm defoliation. Once an acceptable level of hazard has been accomplished, it can be maintained by periodic burning.

Prescribed fire can also be used to maintain shaded fuel breaks in a fuel-free condition.

Silviculture

Where timber management is the objective, fire can be used to dispose of slash, prepare seedbeds, control species composition, and to reduce the probability of stand-destroying wildfires. Ponderosa pine is often a favored timber species on Group Four habitat types. If this is the case, fire can be used to remove unwanted Douglas-fir regeneration once the ponderosa pine reaches about 5 inches (about 13 cm) in diameter. Wright (1978) recommends that there be an adequate number of trees 10 to 12 ft (3-3.7 m) tall before regular prescribed burning begins, although low intensity fires will leave trees 6 to 8 ft (1.8-2.4 m) tall unharmed. Larger Douglas-fir trees will also survive most low intensity surface fires; so there need be no concern about completely eliminating Douglas-fir from the stand. Where butt rot is common on overstory Douglas-fir, however, increased mortality should be expected.

Range and Wildlife Habitat Management

Big game winter and spring range can be rejuvenated with properly applied prescribed fire, especially in the spring. Such fires can remove accumulated dead plant materials, recycle nutrients, regenerate mature and decadent shrubs, and increase distribution and production of nutrient-rich grasses, forbs, and legumes. Prescribed fire can be used to increase the nutritional value of critical wintering and fawning habitat, and thereby reduce neonatal fawn losses of mule deer (Schneegas and Bumstead 1977).

Recreation and Esthetics

Prescribed fire can be used to fireproof the areas immediately adjoining campgrounds. Such treatment not only reduces fire hazard, but also improves viewing and travel from the campground to the surrounding forest.

A similar use of fire is for fireproofing and improving esthetic values along travel routes. An example from the Lolo National Forest would be the use of fire along the Lolo Trail, not only to reduce wildfire hazard, but, more importantly, to preserve the historical scene of an open forest with large ponderosa pine trees.

Fire Use Considerations

The considerations regarding fire use identified in the discussion of fire management considerations for Fire Group Two habitat types also apply here.

FIRE GROUP FIVE

COOL, DRY DOUGLAS-FIR HABITAT TYPES

Habitat type - phase (Pfister and others 1977)	Ecoclass code (On and Losensky 1977)
Pseudotsuga menziesii/Festuca idahoensis h.t. (PSME/FEID), Douglas-fir/Idaho fescue.	CD-1-220
Pseudotsuga menziesii/Carex geyeri h.t. (PSME/CAGE), Douglas-fir/elk sedge.	CD-3-330

FIRE GROUP SIX

MOIST, DOUGLAS-FIR HABITAT TYPES

Habitat type - phase (Pfister and others 1977)	Ecoclass code (On and Losensky 1977)
Pseudotsuga menziesii/Vaccinium caespitosum h.t. (PSME/VACA), Douglas-fir/dwarf huckleberry.	CD-2-250
Pseudotsuga menziesii/Physocarpus malvaceus h.t.-*Physocarpus malvaceus* phase (PSME/PHMA-PHMA), Douglas-fir/ninebark-ninebark phase.	CD-2-261
Pseudotsuga menziesii/Vaccinium globulare h.t.-*Vaccinium globulare* phase (PSME/VAGL-VAGL), Douglas-fir/blue huckleberry-blue huckleberry phase.	CD-3-281
Pseudotsuga menziesii/Vaccinium globulare h.t.-*Arctostaphylos uva-ursi* phase (PSME/VAGL-ARUV), Douglas-fir/blue huckleberry-kinnikinnick phase.	CD-2-282
Pseudotsuga menziesii/Vaccinium globulare h.t.-*Xerophyllum tenax* phase (PSMA/VAGL-XETE), Douglas-fir/blue huckleberry-beargrass phase.	CD-2-283
Pseudotsuga menziesii/Linnaea borealis h.t.-*Symphoricarpos albus* phase (PSME/LIBO-SYAL), Douglas-fir/twinflower-snowberry phase.	CD-5-291
Pseudotsuga menziesii/Linnaea borealis h.t.-*Calamagrostis rubescens* phase (PSME/LIBO-CARU), Douglas-fir/twinflower-pinegrass phase.	CD-5-292
Psuedotsuga menziesii/Linnaea borealis h.t.-*Vaccinium globulare* phase (PSME/LIBO-VAGL), Douglas-fir/twinflower-blue huckleberry phase.	CD-5-293
Pseudotsuga menziesii/Symphoricarpos albus h.t.-*Calamagrostis rubescens* phase (PSME/SYAL-CARU), Douglas-fir/snowberry-pinegrass phase.	CD-2-312
Pseudotsuga menziesii/Symphoricarpos albus h.t.-*Symphoricarpos albus* phase (PSME/SYAL-SYAL), Douglas-fir/snowberry-snowberry phase.	CD-2-313
Pseudotsuga menziesii/calamagrostes rubescens h.t.-*Arctostaphylos uva-ursi* phase (PSME/CARU-ARUV), Douglas-fir/pinegrass-kinnikinnick phase.	CD-2-322
Pseudotsuga menziesii/Calamagrostis rubescens h.t.-*Calamagrostis rubescens* phase (PSME/CARU-CARU), Douglas-fir/pinegrass-pinegrass phase.	CD-3-323

Group Five and Six habitat types are those that will support substantial amounts of Douglas-fir even under the influence of periodic natural burning. Douglas-fir is the indicated climax species as well as a vigorous member of most seral communities. Ponderosa pine, western larch, and lodgepole pine are seral components whose abundance varies considerably by phase, that is, accidental to major seral (appendix C) (Pfister and others 1977). For Group Six habitat types having seral communities dominated by lodgepole pine, the reader should also refer to Fire Group Seven. The undergrowth consists of herbs and low shrubs.

At low elevations, Group Five and Six sites can be found on all aspects. As elevation increases (and on cooler or moister sites), ponderosa pine becomes less important and larch and lodgepole pine increase. Group Five and Six habitat types together cover 29 percent of the Lolo National Forest.

Relationship of Major Tree Species to Fire

Pinus ponderosa

Fire's role as a seedbed-preparing agent is important to the success of ponderosa pine in Group Six. The higher productivity of these sites, as compared with Groups Two and Four, creates more duff and more aggressive undergrowth competition. It is doubtful that ponderosa would be able to regenerate successfully in these habitat types without periodic ground fires to remove duff and thin the understory and undergrowth. Ponderosa may form pure or nearly pure stands depending on fire history and available seed source. Ponderosa pine is essentially absent on Group Five habitat types on the Lolo National Forest.

Ponderosa pine is more vulnerable to crown damage in Group Six because the surrounding mixture of uneven-aged conifers creates a fuel ladder that can carry fire into the top of the pine. The density of some stands promotes wind-driven crown fires.

Pseudotsuga menziesii

Douglas-fir is much more aggressive in these groups than in Group Four because of increased seedling survival in the cool, moist ground-level microhabitat. Douglas-fir is the climax species and is favored by protection from fire. Absence of fire results in a dense understory of fir saplings that compete with one another for light and with mature overstory trees for moisture. Nearly pure stands of fir can result from fire exclusion. Douglas-fir is often the only tree found on Group Five habitat types on the Lolo National Forest.

Dense sapling thickets can form an almost continuous layer of flammable foliage about 10 to 26 ft (3 to 8 m) above the ground that will support wind-driven crown fires. Even small thickets of saplings provide a route by which surface fires can reach the crowns of mature trees.

Larix occidentalis

Western larch is similar to ponderosa pine in that it possesses a thick, fire-resistant bark and has a tendency to self-prune its lower branches. Light-to-moderate ground fires, therefore, have little effect on mature larch. Even young seedlings will often survive high temperatures for short durations.

Since larch is a shade-intolerant species, a disturbance such as fire is essential for removing competing vegetation and creating a mineral soil seedbed. The light, winged seeds of western larch are readily dispensed across newly burned areas.

Larch's deciduous nature makes it unusually resistant to crown scorch injury. Since larch grows a new crop of needles annually, defoliation is not as great a hardship for it as for conifers that retain their needles for 3 or more years.

In Group Six stands, larch shares with ponderosa pine the role of a pioneer invader, but it usually appears as a minor seral element associated with pine. In the more mesic habitat types, larch replaces ponderosa pine to some extent.

Larch and lodgepole pine frequently occupy the same role as seral species. Since larch lives longer and grows taller, it eventually surpasses the lodgepole component.

Pinus contorta

Lodgepole pine is well known for its role as a fire-follower. Although moderately resistant to fire injury, many lodgepole pines bear serotinous cones that will not open to release their seeds until after heat treatment. Following a stand-destroying fire, this reseeding capacity gives lodgepole pine a substantial advantage over other tree species in getting established on the site. Rapid growth and the ability to set seed while still in the sapling stage help it to maintain dominance.

In Group Six, lodgepole pine is generally confined to the role of a minor seral component because it is readily "shaded-out" by maturing Douglas-fir and larch. Typically, lodgepole appears within 30 years after a fire and is shaded-out roughly a century later (50 to 200 years).

Lodgepole regeneration frequently takes the form of closely spaced "doghair" thickets. Such thickets are very susceptible to fire damage because of the density of saplings, flammable foliage, thin resinous bark, and down and dead fuels. Lodgepole can become a fire climax stand under these conditions, because regeneration naturally favors another lodgepole thicket.

Forest Fuels

Fuel loads measured in Fire Group Five and Six stands ranged from about 1 ton/acre to over 75 tons/acre (0.2 to 16.8 kg/m^2). Within this range three rather distinct levels of loading can be recognized. For the purpose of this discussion, these levels have been identified as light, medium, and heavy.

Light Fuel Loads

An average load of about 3 tons/acre (0.7 kg/m^2) and a range of from 1 to 6 tons/acre (0.2 to 4.5 kg/m^2) characterizes the light loadings in Fire Group Five and Six stands. Fuels in these stands consist almost entirely of scattered twigs and branchwood less than 3 inches (7.6 cm) in diameter. Larger materials rarely account for more than 1 ton/acre (0.2 kg/m^2). Figure 5 shows such situations on the Lolo National Forest.

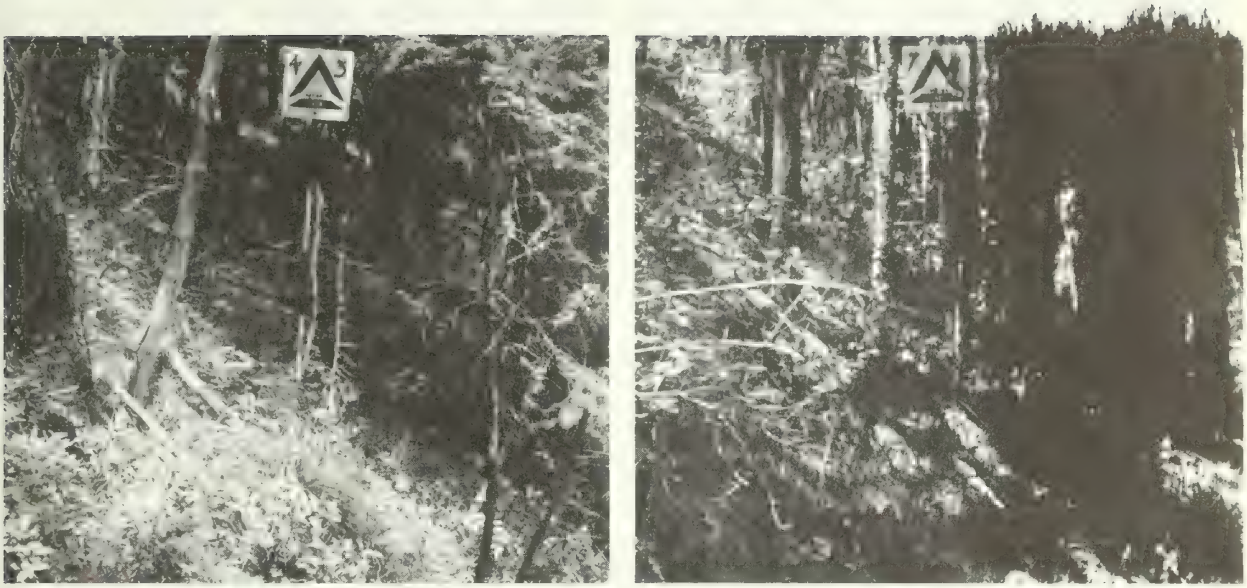


Figure 5.--Examples of light fuel loads in Group Five and Six stands. Stand 43 is a Douglas-fir stand on a *Pseudotsuga menziesii/Vaccinium globulare* h.t.-*Xerophyllum tenax* phase (PSME/VAGL-XETE), Douglas-fir/blue huckleberry-beargrass phase. Stand 71 is a western larch/Douglas-fir stand on a *Pseudotsuga menziesii/Physocarpos malvaceus* h.t.-*Psycocarpos malvaceus* phase (PSME/PHMA-PHMA), Douglas-fir/ninebark-ninebark phase. Total load of down woody fuel, load by size class, and stand age are shown in table 3.

Medium Fuel Loads

Medium fuel loads range from 6 to 20 tons/acre (1.4 to 4.5 kg/m^2) with 12 tons/acre (2.7 kg/m^2) being average. Materials larger than 3 inches (7.6 cm) in diameter usually account for more than half the total load. Scattered deadfalls that accumulate over the life of the stand are the most abundant fuels except where heavy downfall from natural thinning is a factor. Figure 6 shows four examples of medium fuel loads in Group Five and Six stands.

Heavy Fuel Loads

Heavy loads in Group Five and Six stands average about 39 tons/acre (8.7 kg/m^2), but range from about 20 tons/acre to over 75 tons/acre (4.5 kg/m^2 to 16.8 kg/m^2). Examples of heavy fuel loads are shown in figure 7.

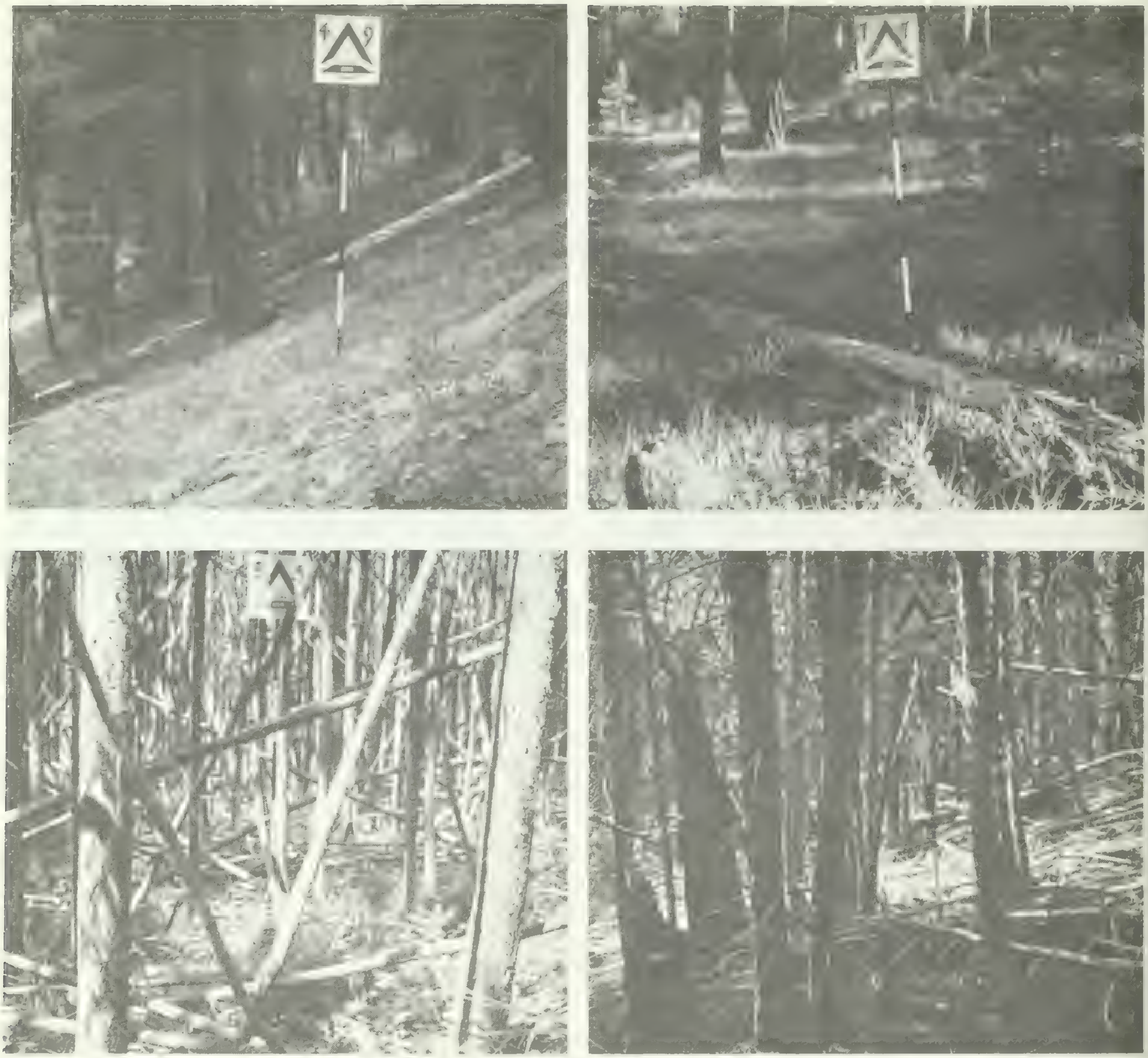


Figure 6.--Examples of medium fuel loads for Group Five and Six stands. Stand 49 is a Douglas-fir stand on a *Pseudotsuga menziesii/Calamagrostis malvaceus* h.t.-*Calamagrosti rubescens* phase (PSME/CARU-CARU), Douglas-fir/pinegrass-pinegrass phase. Stand 77 is a ponderosa pine/western larch/Douglas-fir stand on a *Pseudotsuga menziesii/Calamagros rubescens* h.t.-*Artostaphylos uva-ursi* phase (PSME/CARU-ARUV), Douglas-fir/pinegrass-kinnikinnick phase. Stand 85 is a lodgepole pine stand on a *Pseudotsuga menziesii/Vaccinium globulare* h.t.-*Xerophyllum tenax* phase (PSME/VAGL-XETE), Douglas-fir/blue huckleberry-beargrass phase. Stand 86 is a Douglas-fir stand on a *Pseudotsuga menziesii/Physocarpus malvaceus* h.t.-*Pysocarpus malvaseus* phase (PSME/PHMA-PHMA), Douglas-fir/ninebark-ninebark phase. Total fuel loads, loading by size class, and stand age are given in table 3.

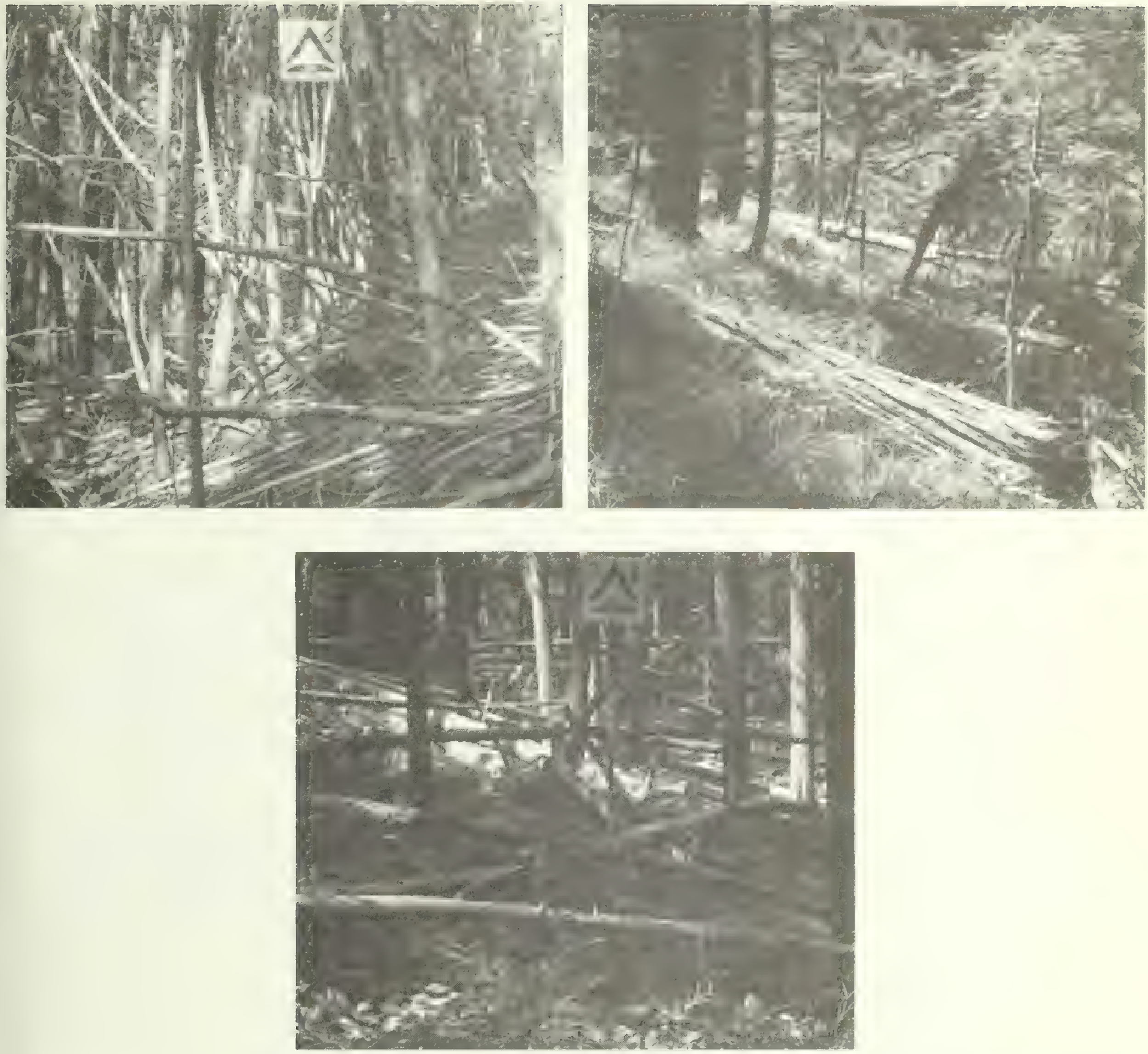


Figure 7.--Examples of heavy fuel loads in Group Five and Six stands. Stand 6 is a lodgepole pine stand, stand 48 is a Douglas-fir stand, and stand 28 is a western larch/ Douglas-fir stand. All are on a *Pseudotsuga menziesii/Vaccinium globulare* h.t.- *Xerophyllum tenax* phase (PSME/VAGL-XETE), Douglas-fir/blue huckleberry-beargrass phase. Total fuel load, loading by size class, and stand age are shown in table 3.

Table 3.--*Fuel loading by size class for nine Fire Group Five and Six stands (fig. 5 to 7)*

Stand number	Age	Size class (inches)							
		0-1/4	1/4-1	1-3	3-6	6-10	10-20	20+	Total
	Years	- - - - - - - - - - - - - - - - *Tons/acre* - - - - - - - - - - - - - - - -							
43	85	0.44	1.20	0.80	0.50	0	0	0	1.38
71	75	0.48	1.90	2.10	0.83	0	0	0	5.31
49	295	0.36	0.90	1.20	0.55	1.00	3.71	0	7.22
77	190	0.08	0.50	0.80	0.12	2.04	8.77	0	12.31
85	70	0.45	1.90	4.30	0.20	1.61	4.22	0	12.68
86	65	0.77	1.80	3.70	0.39	7.52	1.99	0	16.17
6	80	0.32	0.80	0.70	0.84	1.11	0	0	28.23
48	190	0.22	1.10	1.90	3.30	14.55	17.42	3.52	42.01
28	100	0.27	1.50	4.30	12.23	17.01	2.01	36.63	73.95

Role of Fire

Fire appears to be important in Groups Five and Six as a seedbed-preparing and stand-thinning agent. Fire favors the pioneer species ponderosa pine, lodgepole pine, and western larch in Group Six. In stands that have escaped regular ground fires for several decades, flames can climb through the Douglas-fir understory into the overstory, developing into a crown fire or torching the canopy.

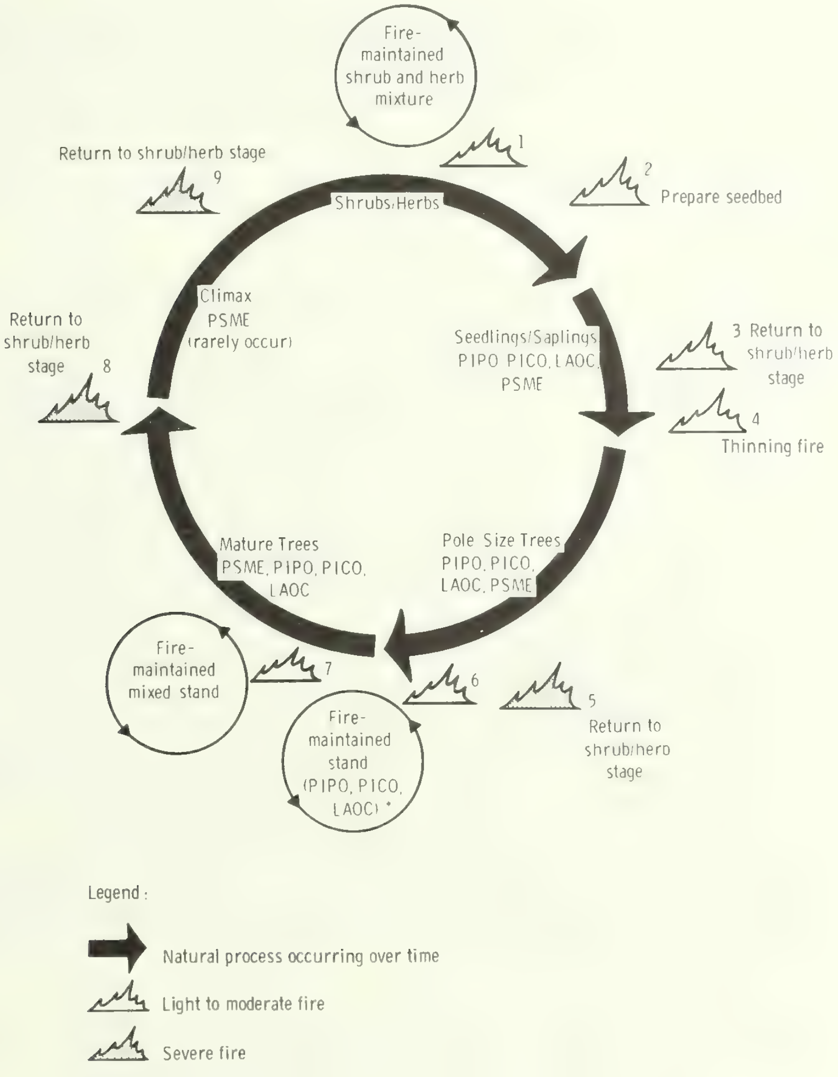
Fire has a demonstrable effect on wildlife habitat in these Groups through its effects on food plants. An important species in some habitat types is *Vaccinium globulare* (blue huckleberry). Light burning in the early spring stimulates huckleberry to produce more shoots. Late summer or fall burning, however, reduces the number of huckleberry plants since it tends to be more intense. Because of heavy use by grouse, bear, deer, and elk, spring burning is preferred in areas designated for wildlife habitat.

The historical frequency of fire in a group of stands similar to those found in Groups Five and Six was given by Arno (1976). The mean interval of fire occurring somewhere in sizeable stands (100 to 200 acres; 40 to 81 hectares) was about 28 years with a range of 5 to 67 years during the two centuries from 1700 to 1900.

Succession Diagram

A comparison of figure 3 with figure 8 shows that succession in Groups Five and Six habitat types is very similar to that of Group Four. Ponderosa pine is followed by lodgepole pine and western larch as seral species.

Secondary succession in Groups Five and Six begins with a mixture of shrubs and herbs. Conifer seedlings may be a minor component of this stage. Frequent fires will maintain a predominant shrub and herb community by killing conifer regeneration (fig. 8, No. 1). Tree seedlings may become established in the seedbed created by fire (fig. 8, No. 2) or germinate on the site during a prolonged period without disturbance. Conifers appearing in this stage will depend on the seed source, but, generally, there will be at least two species represented especially in Group Six. Because Douglas-fir is more aggressive in these habitat types than in Group Four, it is often found in young stands.


Fire-maintained shrub and herb mixture
1
Return to shrub/herb stage
9
2
Prepare seedbed
Shrubs/Herbs
Climax PSME (rarely occur)
Seedlings/Saplings PIPO PICO, LAOC, PSME
Return to shrub/herb stage
8
3 Return to shrub/herb stage
4
Thinning fire
Mature Trees PSME, PIPO, PICO, LAOC
Pole Size Trees PIPO, PICO, LAOC, PSME
Fire-maintained mixed stand
7
6
5
Return to shrub/herb stage
Fire-maintained stand (PIPO, PICO, LAOC) *
Legend:
Natural process occurring over time
Light to moderate fire
Severe fire

* Fire-maintained stands of ponderosa pine, lodgepole pine, or western larch could occur in PSME/VACA, and PSME/CARU-ARUV habitat types.

Figure 8.--Forest succession in Fire Groups Five and Six: Douglas-fir climax series habitat types dominated by Douglas-fir.

A fire occurring during the seedling/sapling stage will have the same effect it would have had in previous groups. The vegetation will be returned to a shrub/herb community (fig. 8, No. 3) or the regeneration will be thinned (fig. 8, No. 4). More continuous ground fuels occurring in these habitats increase the probability of more complete burns.

When the trees are pole size, a severe fire could destroy the stand (fig. 8, No. 5). Site productivity is moderate-to-high in Group Five and Six habitats, and dense stands do develop. Fuel ladders and suppression mortality increase the potential destructiveness of fire during this successional stage.

Ground and surface fires of lower intensity maintain open seral stands. In some of the habitat types [*Pseudotsuga menziesii/Vaccinium caespitosum* h.t. (PSME/VACA), Douglas-fir/dwarf huckleberry and *Psuedotsuga menziesii/Calamagrostis rubescens* h.t.-*Arctostaphylos uva-ursi* phase (PSME/CARU-ARUV), Douglas-fir/pinegrass-kinnikinnick phase], ponderosa, lodgepole, and/or larch may be dominant (fig. 8, No. 6). In the other habitats where Douglas-fir is more aggressive, the fir will usually dominate a mixture of the seral trees (fig. 8, No. 7). The species composition largely depends upon the seed source and the influence of past fires.

Long periods without fire can result in the establishment of a dense Douglas-fir understory that can act as a fuel ladder to the overstory. A severe, stand-destroying fire in a closed mature stand will recycle the site to a shrub/herb stage (fig. 8, No. 8).

A climax forest composed only of Douglas-fir is not likely to occur in the Group Six habitat types where ponderosa, lodgepole, and larch are prominant components, primarily because the interval between fires is shorter than the life span of seral trees. However, in Group Five and some Group Six stands, notably on *Pseudotsuga menziesii/Physocarpus malvaceus* h.t.-*Physocarpus malvaceus* phase (PSME/PHMA-PHMA), Douglas-fir/ninebark-ninebark phase and *Pseudotsuga menziesii/Calamagrostis rubescens* h.t.-*Calamagrostis rubescens* phase (PSME/CARU-CARU), Douglas-fir/pinegrass-pinegrass phase often achieve near-climax status because Douglas-fir is the only important tree even in early succession. Intervening fires are generally light-to-moderate and do not disrupt succession. A stand-destroying fire in a climax stand would return the vegetation to a shrub/herb-dominated community (fig. 8, No. 9).

Huckleberry can be stimulated by light burning that leaves most of the duff, or it can be temporarily reduced by a moderate fire that burns down to mineral soil.

Fire Management Considerations

Opportunities for using prescribed fire (planned ignition) to accomplish management objectives are probably greater in Group Five and Six habitat types than in any others. Often, a single fire prescription can be written to accomplish a variety of management objectives with the same fire.

Fire management opportunities fall within four general categories: wildfire hazard reduction, silviculture, range and wildlife habitat management, and recreation and esthetics.

Wildfire Hazard Reduction

On sites where ponderosa pine and western larch are dominant seral components and where overstory Douglas-fir trees are large, fire can be used to reduce the probability of surface fires of high intensity by reducing the accumulated woody debris on the forest floor or the slash resulting from logging activities. Similarily, crown fire potential can be reduced by using fire to remove dense understories or patches of shrub and tree regeneration. Norum's (1977) guidelines should be used to write fire prescriptions for safely reducing wildfire hazard in Group Five and Six stands.

Fire might also be useful for reducing hazard in thinning slash if ponderosa pine and western larch leave trees are about 5 inches (13 cm) in diameter or larger and lower branches are high enough above the forest floor so fire will not be carried to the crown. Several entries with fire might be necessary to safely reduce hazard to acceptable limits in heavily thinned stands.

Where shaded fuel breaks have been installed, periodic prescribed fire can be used to maintain these areas in a fuel-free condition.

Silviculture

Fire can be used to favor ponderosa pine and western larch at the expense of Douglas-fir where this is silviculturally desirable. A relatively light surface fire can be used to remove Douglas-fir understories; thereby reducing the competition for moisture and nutrients. Where such fires burn hot enough to create openings in the stand or to bare mineral soil in existing openings, ponderosa pine and western larch regeneration may become established.

On logged areas, fire can prepare sites that are immediately favorable for establishment of ponderosa pine and western larch regeneration by providing a mineral soil seedbed. Norum's (1977) prescribed fire guidelines provide a basis for writing fire prescriptions that allow the manager to remove only as much duff as is necessary to obtain desired stocking. Such fires should also reduce grass and shrub competition for the new seedlings. Where large amounts of pinegrass (*Calamagrostis rubescens*) and elk sedge (*Carex geyeri*) are present in the understory care should be taken to prescribe a fire hot enough to kill the root crowns. A light fire will often encourage the pinegrass and elk sedge to the detriment of tree seedlings.

Range and Wildlife Habitat Management

Fire can be used to stimulate the production of wildlife food in some Group Five and Six habitat types. Light and medium intensity surface fires will result in increased density and nutrient content of blue huckleberry (*Vaccinium globulare*) and other sprouting shrubs where present. This in turn should result in increased berry production for grouse, bear, and other wildlife, as well as for humans. Highly palatable new shoot growth on *Vaccinium* and other sprouting shrubs will provide increased browse for deer, elk, and other wildlife. Grass and forb production may also be increased and their nutrient content temporarily enhanced. Hot surface fires will favor conifer reproduction and shrubs such as snowbrush ceanothus (*Ceanothus velutinus*).

In slash areas, fire will often result in a tremendous increase in the abundance of palatable shrub species that were present in the preburn stand along with conifer seedlings. A similar situation will usually follow stand replacement wildfires. Grass and forb production will be increased tremendously in both these situations.

Fire Use Considerations

The considerations regarding fire use identified in the discussion of fire management considerations for Fire Group Two also apply here.

When planning fire use in Group Five and Six habitat types, fire managers should use the results and recommendations reported by DeByle (1976), Miller (1977, 1978), Stark (1977), Stark and Steele (1977), Norum (1976, 1977), Beaufait and others (1977), Packer and Williams (1976), Shearer (1975), Packer (1973), and Steele and Beaufait (1969 All of the studies reported in these publications were conducted in Group Five and Six habitat types on or near the Lolo National Forest. Fire managers should pay particular attention to the differences in fire response between northerly and southerly exposures, especially as they relate to vegetation development and erosion potential. Research results suggest that high intensity fires be avoided on steep, dry south slopes.

FIRE GROUP SEVEN

COOL, HABITAT TYPES USUALLY DOMINATED BY LODGEPOLE PINE

Habitat type - phase (Pfister and others 1977)	Ecoclass code (On and Losensky 1977)
Picea/Linnaea borealis h.t. (PICEA/LIBO), spruce/twinflower.	CE-5-470
Abies lasiocarpa/Vaccinium caespitosum h.t. (ABLA/VACA), subalpine fir/dwarf huckleberry.	CS-4-640
Abies lasiocarpa/Calamagrostis canadensis h.t.- *Vaccinium caespitosum* phase (ABLA/CACA-VACA), subalpine fir/bluejoint-dwarf huckleberry phase.	CS-7-654
Abies lasiocarpa/Linnaea borealis h.t.- *Vaccinium scoparium* phase (ABLA/LIBO-VASC), subalpine fir/twinflower-grouse whortleberry phase.	CS-4-663
Abies lasiocarpa/Xerophyllum tenax h.t.- *Vaccinium scoparium* phase (ABLA/XETE-VASC), subalpine fir/beargrass-grouse whortleberry phase.	CS-4-692
Abies lasiocarpa/Vaccinium globulare h.t. (ABLA/VAGL), subalpine fir/blue huckleberry.	CS-4-720

Group Seven is composed of habitats which, regardless of theoretical climax species are usually dominated by lodgepole pine because of the fire regimen (Pfister and others 1977, appendixes B and C-1). The group is intended to include sites where lodgepole is a "dominate seral," as well as those where it is a "persistent" dominant. In *Picea/Linnaea borealis* (PICEA/LIBO), spruce/twinflower and *Abies lasiocarpa/Vaccinium globulare* (ABLA/VAGL), subalpine fir/blue huckleberry habitat types, Douglas-fir can be a major seral species (appendix C). Only 0.5 percent of the Lolo National Forest is covered by these habitat types.

Relationship of Major Tree Species to Fire

Pinus contorta

Two effects of fire on lodgepole pine stands are markedly important in Group Seven. First, light-to-moderate intensity ground fire thins the understory and prepares a mineral bed for the seeds released from serotinous cones. In some cases, the frequency of fire prevents the successful establishment of more shade-tolerant species, such as Douglas-fir, spruce, and subalpine fir.

Second, lodgepole forests of this group seem to invite stand-destroying wildfires. Mountain pine beetle epidemics can create enormous amounts of downfall and standing snags. Down and dead wood provide abundant fuel for an intense fire. Wind-driven crown fires cause stand replacement over large areas. Abundant seed supplies after such fires, provided by lodgepole's serotinous cones, virtually assure that recovery will be dominated by lodgepole. Often the result is very densely stocked, even-aged stands.

Thus, fire insures perpetuation of the lodgepole pine forest, maintaining a "fire climax" community.

The conditions under which lodgepole pine forests develop may vary considerably and the precise mechanisms may differ from one site to another, but the net effect is similar. Aside from serotinous cones, other silvical characteristics that contribute to establishment success are seed viability, germination energy, rapid growth, seedling survival in a wide array of microsites, and prolific seed production, that is, having good crops at 1- to 3-year intervals. These features enable lodgepole to gain early dominance.

In some forested regions, not including the Lolo National Forest, self-regenerating stands of lodgepole pine occur in habitats unsuitable for other conifers. These situations usually represent special conditions of edaphic features and/or topographic features (such as frost pockets, nightly accumulations of cold air, and subalpine climate). These areas do not frequently burn because widely spaced trees, low fuel levels, low, scattered undergrowth, and gentle slopes create situations unfavorable for fire spread. Cones are nonserotinous and so do not require a heat treatment for seed dispersal.

Abies lasiocarpa

Subalpine fir is rated as the least fire-resistant northern Rocky Mountain conifer because of its thin bark, resin blisters, low and dense branching habit, high foliage flammability, and moderate-to-high stand density in mature forests. As a result, fire most often acts as an agent of replacement when it burns through a subalpine fir stand. Even light ground fires have the potential of cooking the cambium or of spreading into the ground-hugging branches up into the crown.

Subalpine fir can occur in the initial stand with lodgepole pine because it germinates successfully on a fire-prepared seedbed; however the fir is a minor component, and is slower growing, and therefore, is not as conspicuous as the pine. If forest succession is undisturbed, the fir will eventually take over the site because it germinates and grows in shade. Subalpine fir can occur in the initial stand or invade during a later successional stage.

Picea engelmannii

Although slightly less susceptible to fire damage than subalpine fir, Engelmann spruce does succumb easily to fire. The dead, dry, flammable lower limbs, low-growing canopy, thin bark, and lichen growth in the branches contribute to the species' vulnerability. The shallow root system is readily subject to injury from fire burning through the duff. Older trees that have deep accumulations of litter around their bases are particularly susceptible. The season of high fire risk is comparatively short, however, in the generally cool and moist habitats where spruce grows.

Even though spruce is considered a late succession species, seedlings have been observed as members of the fire-initiated stand with lodgepole. With time and without disturbance, spruce slowly dominates the stand as conditions become unsuitable for pine. This may be a temporary phase on sites where subalpine fir is the true potential climax dominant.

Forest Fuels

Available fuel data show a range of fuel loading from 3.5 tons/acre to 35 tons/acre (0.8 kg/m^2 to 7.8 kg/m^2). Average fuel load is about 20 tons/acre (4.5 kg/m^2). In young stands, fuels are often the result of natural thinning or downfall of dead overstory trees from the previous stand. In older stands, accumulated downfall of insect-killed trees is often the primary source of fuel. Figure 9 shows examples of light and moderate fuel loads in young stands.

Heavy fuel loads can and do occur in stands of this group, although such situations were not reflected in either of the data bases available. This is probably due to the small acreage of old stands in Fire Group Seven habitat types on the Lolo National Forest

Table 4.--*Fuel loadings by size class for four Fire Group Seven stands (fig. 9)*

Stand number	Age	Size class (inches)							Total
		0-1/4	1/4-1	1-3	3-6	6-10	10-20	20+	
	Years	Tons/acre							
1	80	0.55	0.90	3.80	1.42	0.40	0	0	7.07
35A	125	0.32	1.20	5.10	4.27	1.09	0	0	11.98
49A	165	0.32	1.40	8.10	11.82	1.02	0	0	22.66
81	50	0.26	0.80	2.40	2.82	6.31	22.14	0	34.73

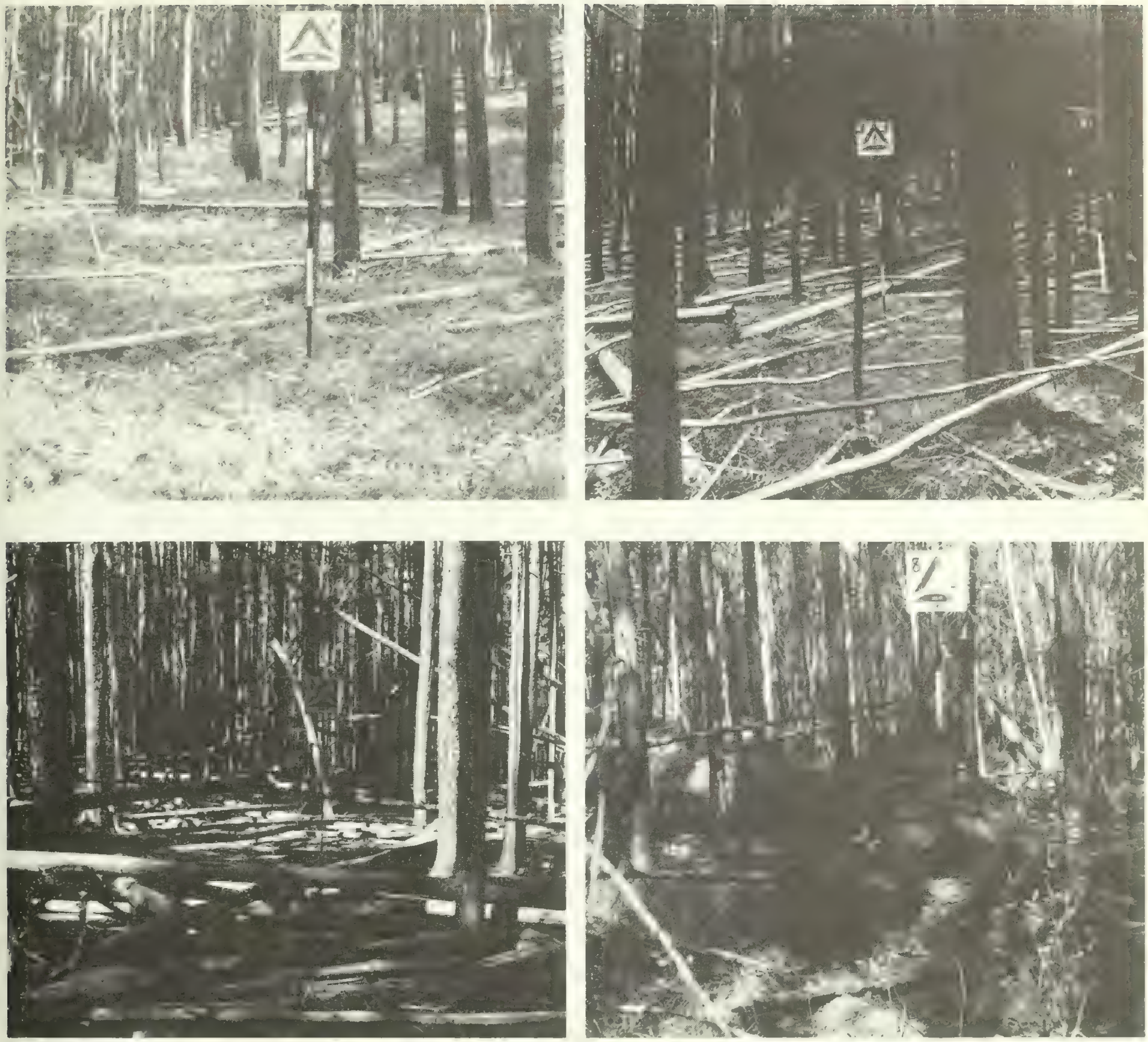


Figure 9.--A range of fuel loads in Group Seven stands. Stand 1 is a lodgepole pine stand on an *Abies lasiocarpa/Vaccinium caespitosum* h.t. (ABLA/VACA), subalpine fir/bluejoint. Stand 35A is a lodgepole pine stand on an *Abies lasiocarpa/Vaccinium globulare* h.t. (ABLA/VAGL), subalpine fir/blue huckleberry. Stand 49A is a lodgepole pine stand on an *Abies lasiocarpa/Vaccinium caespitosum* h.t. (ABLA/VACA), subalpine fir/bluejoint. Stand 81 is a lodgepole pine stand on a *Picea/Linnaea borealis* h.t. (PICEA/LIBO), spruce/twinflower. Table 4 shows total load, loading by size class and stand age.

Role of Fire

The role of fire in seral lodgepole forests is almost exclusively as an agent that perpetuates or renews lodgepole pine. Without periodic disturbance, the more tolerant species can replace lodgepole because it does not regenerate successfully on duff in shaded conditions. Periodic fires interrupt the natural course of succession and increase the proportion of lodgepole with each burn. Burns of moderate intensity disrupt the succession without destroying the stand. The pine's ability to set seed while still in the sapling stage gives it an added advantage over competing species. Within 50 to 100 years after fire in a lodgepole-dominated stand, a reestablished pine cover will exist even though shrubs and herbaceous cover may have become temporarily dominant immediately after the burn. The regeneration of spruce, fir, and other conifers largely depends on the availability of a seed source.

It is in Group Seven that stand-destroying fires assume a dominant role in the overall successional pattern. Brown (1975) discussed the fuel accumulation concept for lodgepole pine forests and illustrated the fire potential trends over time. Lodgepole forests are particularly susceptible to such fires when the stand is overstocked and when suppression mortality and downfall contribute to the fuel situation. Other factors such as dwarf mistletoe infestations, mountain pine beetle outbreaks, and effects of preceding fires often create tremendous fuel accumulations that contribute to violent, widespread burns.

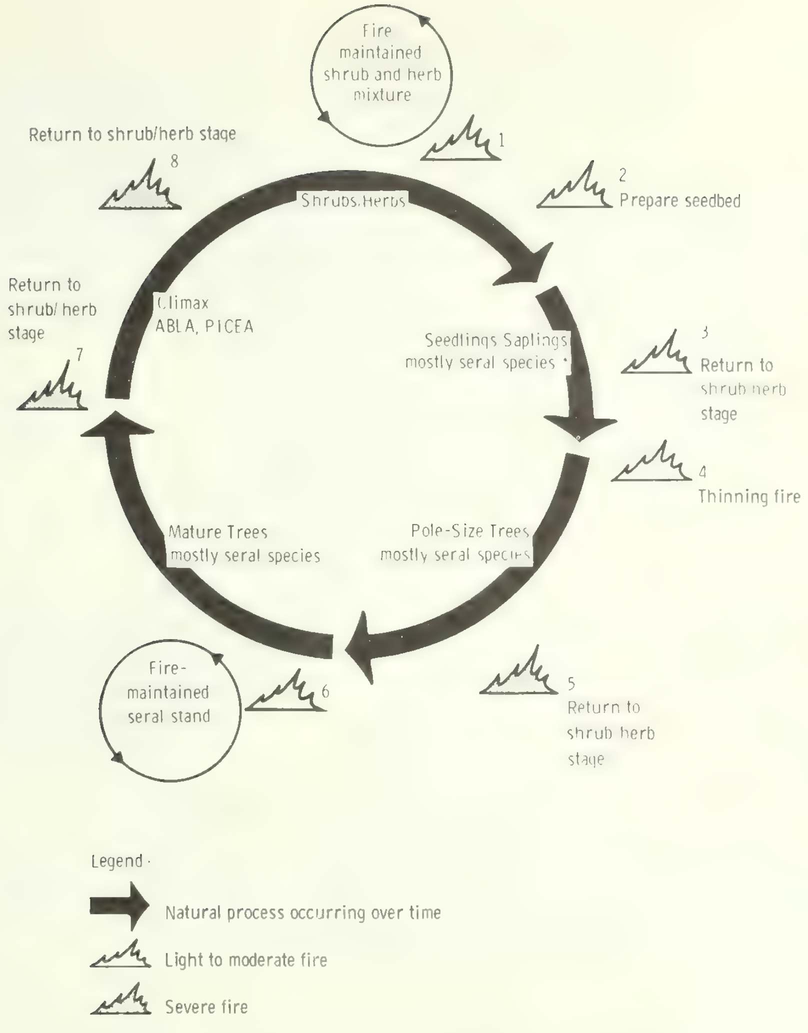
Old-growth spruce/fir stands represent an advanced stage of the fire-initiated lodgepole pine forest. They are not self-perpetuating climax communities. Spruce does not regenerate well under a dense, closed canopy and, in the absence of fire, spruce/fir will progress toward a fir/spruce community. In Group Seven, this would hold for all habitat types except *Picea/Linnaea borealis* h.t. (PICEA/LIBO), spruce/twinflower, in which spruce is the climax tree.

Natural fire frequency in lodgepole stands varies from a few years to 200 years, generally insufficient time for lodgepole to be replaced by climax species. In some areas, the successional status of lodgepole is in doubt because of the scarcity of other conifers within vast tracts of lodgepole forests. In these areas, pine is apparently a fire-maintained disclimax, but it could be an actual climax. Fire would have to be excluded for centuries before the issue could be settled with certainty.

Studies of fire history have shown that fire is a regular feature of lodgepole pine disclimax forests. In Group Seven habitat types occurring in the Bitterroot National Forest, Arno (1976) found that the mean fire-free interval was 21 years with a range of from 3 to 67 years. These figures represent fire occurring somewhere in a sizeable stand (100 to 200 acres [40 to 81 hectares]) and not the frequency of fire reoccurring on a specific site. Gabriel (1976) reported an average of 40 years and Tande (1977) 27 years. Studies from other areas in the Rocky Mountains vary, but are essentially in agreement with these figures. Severe and multiple burns have usually favored lodgepole above all other associated conifers.

Succession Diagram

Figure 10 shows the successional patterns of Fire Group Seven. As in previous groups, the shrub and herb community is perpetuated by repeated, frequent fires (fig. 10, No. 1); however, fire simultaneously prepares a seedbed for lodgepole seedlings (fig. 10, No. 2), or lodgepole seedlings can appear during the shrub/herb stage.


Fire maintained shrub and herb mixture
Return to shrub/herb stage
8
1
2
Prepare seedbed
Shrubs, Herbs
Return to shrub/herb stage
Climax ABLA, PICEA
7
Seedlings Saplings mostly seral species *
3
Return to shrub/herb stage
4
Thinning fire
Mature Trees mostly seral species
Pole-Size Trees mostly seral species
Fire-maintained seral stand
6
5
Return to shrub/herb stage
Legend:
Natural process occurring over time
Light to moderate fire
Severe fire

* Seral species vary with the habitat type. Generally they are lodgepole pine, Douglas-fir, western larch, and western white pine. Subalpine fir and spruce may occur in the seral stages of succession, but their representation will be limited by periodic fires.

Figure 10.--Forest succession in Fire Group Seven: fire-maintained lodgepole pine stands in spruce and subalpine fir climax series habitat types.

Seedlings and saplings are thin-barked and, consequently, not fire resistant. A fire will kill small trees and return the site to the shrub/herb dominated mixture (fig. 10, No. 3) or thin the regeneration by removing only a portion of the trees (fig. 10, No. 4).

Tree regeneration is mostly lodgepole because of its prolific seeding and rapid early growth. With the passage of time, the young trees develop into a stand of pole-size trees. A severe fire during this stage (fig. 10, No. 5) would recycle the vegetation to the original community. Suppression mortality and downfall would increase the likelihood of a fire burning intensely.

Reoccurring light-to-moderate fires will do less damage to maturing lodgepole than to younger stages of invading Douglas-fir, spruce, and subalpine fir (fig. 10, No. 6). Even though some pines will die, the net effect is to increase the relative proportion of lodgepole on the site. A byproduct is the creation of varying amounts of standing dead timber that falls and would support a more severe fire at a later date.

A severe fire in a mature lodgepole forest can kill almost every tree over extensive acreages. The Sleeping Child burn (1961) is an example. However, even in the case of a fire that completely destroys the stand (fig. 10, No. 7), the survival of an abundant seed supply is assured by the serotinous cones that are present high in the canopy.

After 100 to 200 years without major disturbance, a lodgepole forest begins to break up with old age. At this time, substantial amounts of more shade-tolerant trees begin to appear, provided there is a seed source within a reasonable distance. Eventually, a subalpine fir or spruce climax stand can develop. In practice, this is not usual since lodgepole stands become increasingly flammable with age and even more so as the fir and spruce understory becomes established.

On occasion, a subalpine fir or spruce climax forest will eventually exclude lodgepole, burn, and recycle the site to the earliest vegetation stage (fig. 10, No. 8). Stahelin (1943) and Brown (1975) described the successional patterns of lodgepole pine stands and the forest composition from lodgepole to old growth spruce and fir. Their successional diagrams are shown in figures 11 and 12, respectively.

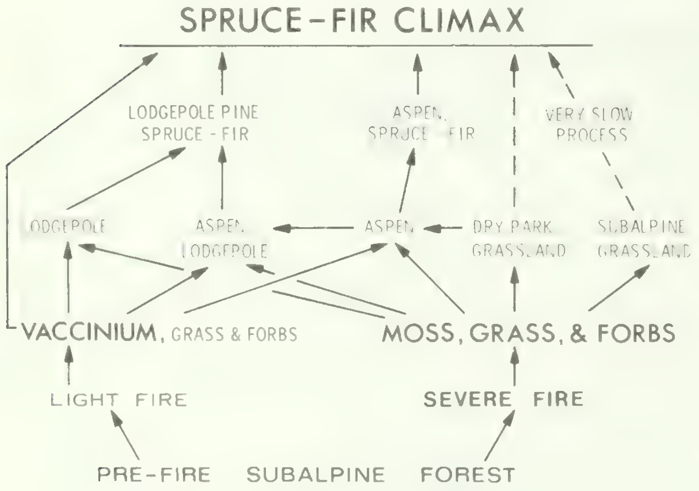


Figure 11.--Major trends of secondary succession on subalpine forests after light and severe fires (adapted from Stahelin 1943).

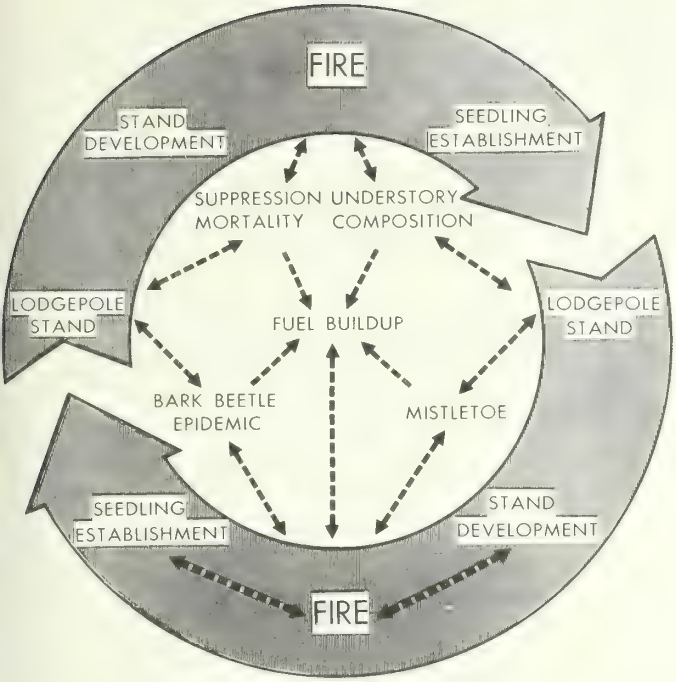


Figure 12.--Lodgepole pine fire cycle showing interrelationships among influences (adapted from Brown 1975).

Fire Management Considerations

Perhaps the primary fire management consideration in Group Seven habitat types is protection from unwanted fire during extended periods of drought and during severe fire weather conditions. Fires at such times often crown and become holocausts that result in complete stand mortality if the lodgepole stand is ready physiognomically to burn (Despain and Sellers 1977).

Opportunities for fire use are limited in natural stands because of the low fire resistance of lodgepole pine, spruce, and subalpine fir. The other side of this problem is that during "safe" fire weather, it is often difficult to sustain a fire in Group Seven stands. Low-to-medium intensity surface fires do occur in Group Seven stands, however. Thus, there may be opportunities to use prescribed fires (either planned or chance ignition) to accomplish specific management objectives.

Prescribed fire has been suggested as a management tool for controlling dwarf mistletoe (*Arceuthobium* spp.). According to Alexander and Hawksworth (1975), prescribed burning, in relation to mistletoe control, can serve two purposes: (1) eliminate infected residual trees in logged-over areas; and (2) destroy heavily infected stands on unproductive sites so that they can be replaced by young healthy stands.

The primary use of prescribed fire in Group Seven habitat types has been and undoubtedly will continue to be for hazard reduction and site preparation in conjunction with tree harvesting. Broadcast burning and windrowing and burning have been the most often used methods of accomplishing these tasks. Successful broadcast slash burning in Group Seven stands will usually yield increased forage production for big game. Slash disposal of any kind will aid big game movement through these stands. The cautions regarding removal of too much woody material discussed in fire management considerations for Group Two habitats also apply here.

As mentioned above, a major concern in the management of lodgepole pine in the general forest zone is the regulation of sweeping crown fires. A key element in this regulation is the establishment and maintenance of an age-class mosaic. This can be accomplished through harvest practices and fire use. In wilderness, however, periodic crown fires play a vital role in natural development of lodgepole pine ecosystems, and their use should be considered when consistent with the need to protect human life, property, and resource values outside wilderness.

Managers should use the information contained in the two-volume proceedings of the symposium: "Management of lodgepole pine ecosystems" (Baumgartner 1973) as a guide for fire management actions in Group Seven habitat types.

FIRE GROUP EIGHT

DRY LOWER SUBALPINE HABITAT TYPES

Habitat type - phase (Pfister and others 1977)	Ecoclass code (On and Losensky 1977)
Abies lasiocarpa/Xerophyllum tenax h.t.- *Vaccinium globulare* phase (ABLA/XETE-VAGL), subalpine fir/beargrass-blue huckleberry phase.	CS-4-691
Tsuga mertensiana/Xerophyllum tenax h.t.- (TSME/XETE), mountain hemlock/beargrass.	CS-4-710

FIRE GROUP NINE

MOIST, LOWER SUBALPINE HABITAT TYPES

Habitat type - phase (Pfister and others 1977)	Ecoclass code (On and Losensky 1977)
Picea/Galium triflorum h.t. (PICEA/GATR), spruce/sweetscented bedstraw.	CS-7-440
Abies lasiocarpa/Oplopanax horridum h.t. (ABLA/OPHO), subalpine fir/devil's club.	CS-7-610
Abies lasiocarpa/Clintonia uniflora h.t.- *Clintonia uniflora* phase (ABLA/CLUN-CLUN), subalpine fir/queencup beadlily-queencup beadlily phase.	CS-6-621
Abies lasiocarpa/Clintonia uniflora h.t.- *Aralia nudicaulis* phase (ABLA/CLUN-ARNU), subalpine fir/queencup beadlily-wild sarsaparilla phase.	CS-6-622
Abies lasiocarpa/Clintonia uniflora h.t.- *Vaccinium caespitosum* phase (ABLA/CLUN-VACA), subalpine fir/queencup beadlily-dwarf huckleberry phase.	CS-6-623

Habitat type - phase	Ecoclass code
Abies lasiocarpa/Clintonia uniflora h.t.- *Xerophyllum tenax* phase (ABLA/CLUN-XETE), subalpine fir/queencup beadlily-beargrass phase.	CS-6-624
Abies lasiocarpa/Clintonia uniflora h.t.- *Menziesia ferruginea* phase (ABLA/CLUN-MEFE), subalpine fir/queencup beadlily-menziesia phase.	CS-6-625
Abies lasiocarpa/Galium triflorum h.t. (ABLA/GATR), subalpine fir/sweetscented bedstraw.	CS-7-630
Abies lasiocarpa/Calamagrostis canadensis h.t.- *Calamagrostis canadensis* phase (ABLA/CACA-CACA), subalpine fir/bluejoint-bluejoint phase.	CS-7-651
Abies lasiocarpa/Calamagrostis canadensis h.t.- *Galium triflorum* phase (ABLA/CACA-GATR), subalpine fir/bluejoint-sweetscented bedstraw phase.	CS-7-653
Abies lasiocarpa/Linnaea borealis h.t.- *Linnaea borealis* phase (ABLA/LIBO-LIBO), subalpine fir/twinflower-twinflower phase.	CS-6-661
Abies lasiocarpa/Linnaea borealis h.t.- *Xerophyllum tenax* phase (ABLA/LIBO-XETE), subalpine fir/twinflower-beargrass phase.	CS-6-662
Abies lasiocarpa/Menziesia ferruginea h.t. (ABLA/MEFE), subalpine fir/menziesia.	CS-6-670
Tsuga mertensiana/Menziesia ferruginea h.t. (TSME/MEFE), mountain hemlock/menziesia.	CS-6-680

Fire Groups Eight and Nine are a collection of habitat types in the spruce and subalpine fir series. Although they encompass a wide variety of conditions, they generally have the same relationship to fire. Fire frequency is low, but fires that do occur are often severe and their effects may be long lasting. These habitat types rarely progress to mature climax stands because of the fire regimen. Group Eight and Nine habitat types cover 32 percent of the Lolo National Forest.

Groups Eight and Nine describe a generalized pattern of fire ecology in subalpine habitats. The specific successional patterns will vary considerably even within a habitat type depending on the composition of the stand and the fire behavior. The roles of associated species vary with the habitat type (appendix C) and specific site conditions.

Relationship of Major Tree Species to Fire

Pinus contorta

Lodgepole pine's role in Groups Eight and Nine is that of an intolerant species whose very existence is dependent upon periodic fires. It is a major component of eral stands in the lower subalpine habitat types. Being an intolerant species, it is unable to regenerate successfully in conditions associated with later forest succession. Its greatest expression is in the fire-initiated stand.

In Groups Eight and Nine, lodgepole differs from its role in Group Seven by not being the dominating seral species. It usually occurs in mixed stands with Douglas-fir, western larch, and western white pine.

Larix occidentalis

Western larch is the most fire-resistant conifer in the northern Rocky Mountains. It is, however, more vulnerable to damage in these habitats because it grows in dense stands in association with low-canopy conifers and tall shrubs that can carry fire into the crowns. It is a subclimax species maintained by fire. It cannot successfully regenerate in the shaded conditions of the later successional stages and will lose dominance to more tolerant species if overtopped.

Larch is a major seral component of Group Eight and Nine stands in northwestern Montana (Pfister and others 1977). Locally, it may occur in nearly pure stands.

Pinus monticola

Western white pine is moderately resistant to fire damage. Resistance is favored by the medium thick bark, moderate flammability of the foliage, the tall stature, especially, and the self-pruning. Abundant resin in old bark, heavy lichen growth, and dense stand habit lessen white pine's resistance, however. Young stands of white pine are vulnerable to crown fires because of their more compact structure.

Western white pine is a fire species that owes its very existence to replacement burns that recycle stands and create early successional habitat. Its characteristic occurrence in nearly pure, even-aged stands is further evidence of stand-replacing fires.

Western white pine is a major component of some stands in northwestern Montana, but it usually grows in association with Douglas-fir, western larch, and lodgepole pine. Because it is an intolerant tree, it is always a subclimax species leading to fir, spruce, cedar, and hemlock forests.

Soil temperature and adequate moisture appear to control germination, but light seems to have little importance since seeds can germinate in shade. Mineral surfaces provide a better seedbed than duff surfaces, but white pine seed is able to lie over in duff for 2 or 3 years then germinate upon the removal of the litter layer.

The early growth of the western white pine seedling is not very rapid, but it is the fastest growing sapling and pole-sized tree in the northern Rockies. The first 30 to 40 years are critical to the development of the stand because during this time dominance and composition are established. Mortality and pruning subsequently determine the fire resistance of the stand and of individual trees.

Pseudotsuga menziesii

Douglas-fir's fire resistant qualities were discussed in Groups Four, Five, and Six. In Groups Eight and Nine, it is a major, fire-promoted component of seral stands in the lower subalpine habitat types. Douglas-fir is more susceptible to fire damage in these groups because it grows in dense stands. Conifer regeneration and tall shrubs provide a fuel ladder for fire to enter the canopy. While the thick bark offers older trees limited protection from surface fires, fires that reach the crowns destroy trees of all ages.

Douglas-fir is more shade tolerant than western larch and the pines. Its ability to endure shade enables it to regenerate after the fire-initiated stand has been established. When shade conditions become too limiting for Douglas-fir, it is replaced by subalpine fir, Engelmann spruce, and hemlock.

Picea engelmannii

In Group Eight and Nine habitats, Engelmann spruce functions primarily as a persistent seral component of the stand. Fire recycles spruce stands, which usually revert to lodgepole pine, Douglas-fir, and western larch mixtures. Spruce can appear in early successional stages if suitable microsites occur for available seed.

Spruce is not an aggressive pioneer. It is a moderate seeder, but seeds are viable over extended periods. Initial establishment and early growth of seedlings are slow, but usually good when encouraged by shade and abundant moisture. Restocking will occur more quickly if some spruce trees survive within the burn than if regeneration is dependent on seed from trees at the fire edge. Pockets of spruce regeneration often become established around such surviving seed trees up to a distance of 300 feet (90 m), the effective seeding distance for spruce. Successful regeneration diminishes 100 to 150 years after establishment due to insufficient sunlight at ground level and accumulating duff. At this point, the more tolerant true firs, western redcedar, and western hemlock begin to successfully regenerate.

Abies lasiocarpa

Subalpine fir has the same relationship to fire in these groups as it does in Group Seven. Its low fire resistance makes it readily vulnerable to death or severe injury from burning. Thus, fire acts as a recycling agent that reduces the fir component and often replaces it with early seral species.

Subalpine fir is the major climax dominant in these groups. Where fires are infrequent, as in the cold, wet habitat types, fir has time to attain dominancy. In the drier and lower elevation habitat types, however, fir is usually subordinate to more aggressive early serals, such as Douglas-fir, lodgepole pine, western larch, western white pine, and sometimes ponderosa pine. Here, fire is more frequent and seral species are more competitive.

Subalpine fir may begin producing cones when only 20 years old, but maximum seed production is by dominant trees 150 to 200 years old. The tree's performance as a seral is enhanced by its ability to germinate and survive on a fairly wide range of seedbeds. Fir has the advantage of a large seed that can quickly produce a vigorous root system.

In a closed canopy situation, establishment and early survival of fir are favored by relatively deep shade. It can exist under low light conditions better than most associated species, but cannot compete successfully with spruce where light intensity exceeds more than 50 percent of full sunlight.

Forest Fuels

Fuel loads in Group Eight and Nine habitat types will range from about 1 ton/acre to more than 80 tons/acre (0.2 to 17.9 kg/m^2). The average load would be about 30 tons/acre (6.7 kg/m^2), which is greater than the average load of any other group. This average does not reflect a central tendency. A load of 10 tons/acre (2.2 kg/m^2), for example, seems to occur just as frequently as a load of 60 tons/acre (13.5 kg/m^2).

The range of fuel loads in Groups Eight and Nine is similar to that of Group Six. An important difference does exist, however. Group Eight and Nine stands have a greater percentage of their fuel load made up of large diameter downfalls. Table 5 and figure 13 show a sequence of increasing fuel loads in this group. Notice that the amount of material less than 3 inches (7.6 cm) in diameter does not change very much from stand to stand. It is the amount of large material that determines the load. This large material is usually distributed fairly evenly throughout the stand, but it may be concentrated as shown in stands 10 and 3 (fig. 13).

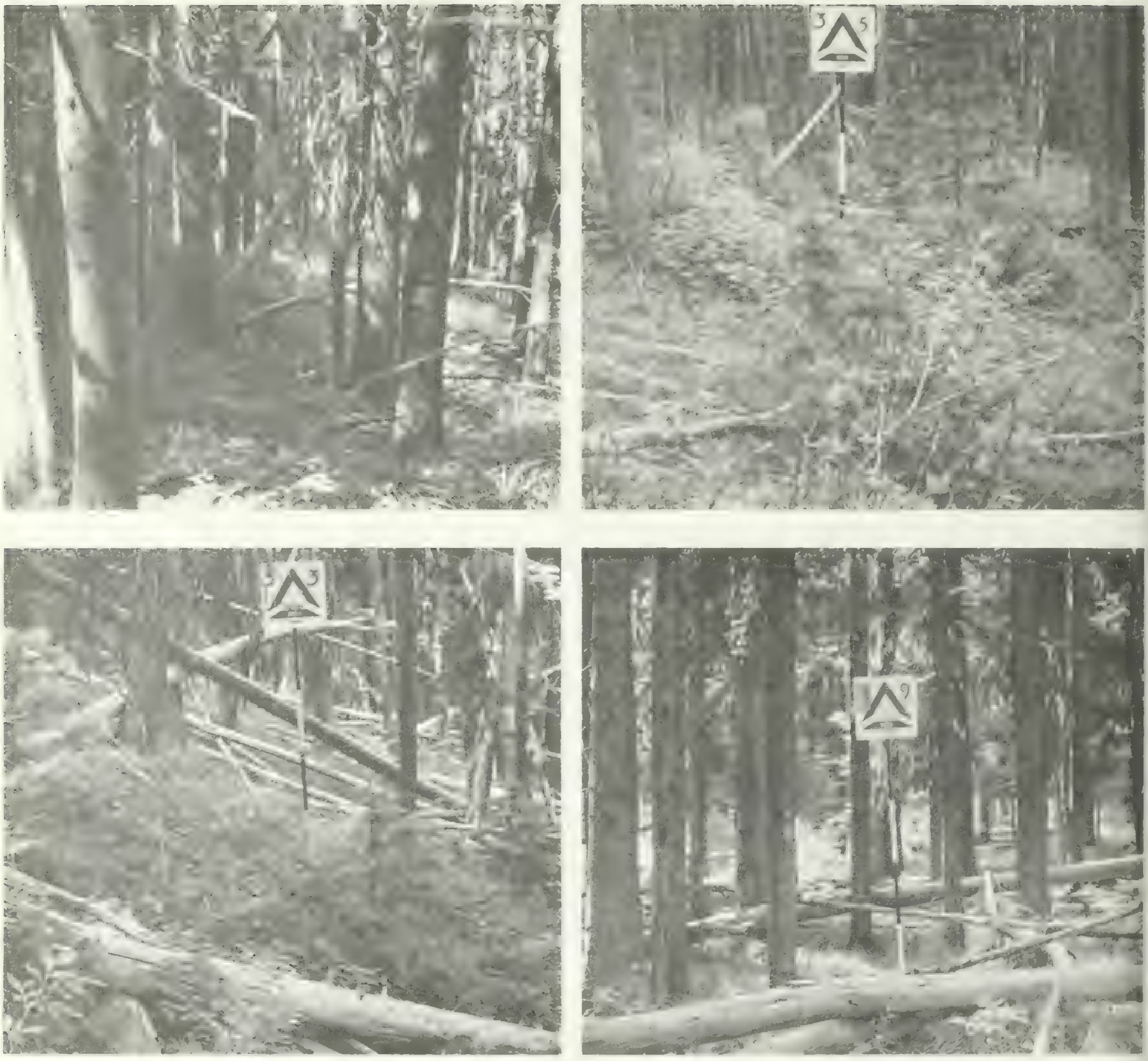


Figure 13.--Examples of typical Group Eight and Nine loads. Stand 53 is a western larch/Douglas-fir stand, all others are Engelmann spruce/subalpine fir. Habitat type are *Abies lasiocarpa/Xerophyllum tenax* h.t.-*Vaccinium globulare* phase (ABLA/XETE-VAGL subalpine fir/beargrass-blue huckleberry phase for stands 45, 59, 22, and 38; *Abies lasiocarpa/Menziesia ferruginea* h.t. (ABLA/MEFE), subalpine fir/menziesia for stands 35, 53, 19, and 10; and *Abies lasiocarpa/Clintonia uniflora* h.t.-*Menziesia ferruginea* phase (ABLA/CLUN-MEFE), subalpine fir/queencup beadlily-menziesia phase for stand 35. Total load and loading by size class and stand age are shown in table 5.

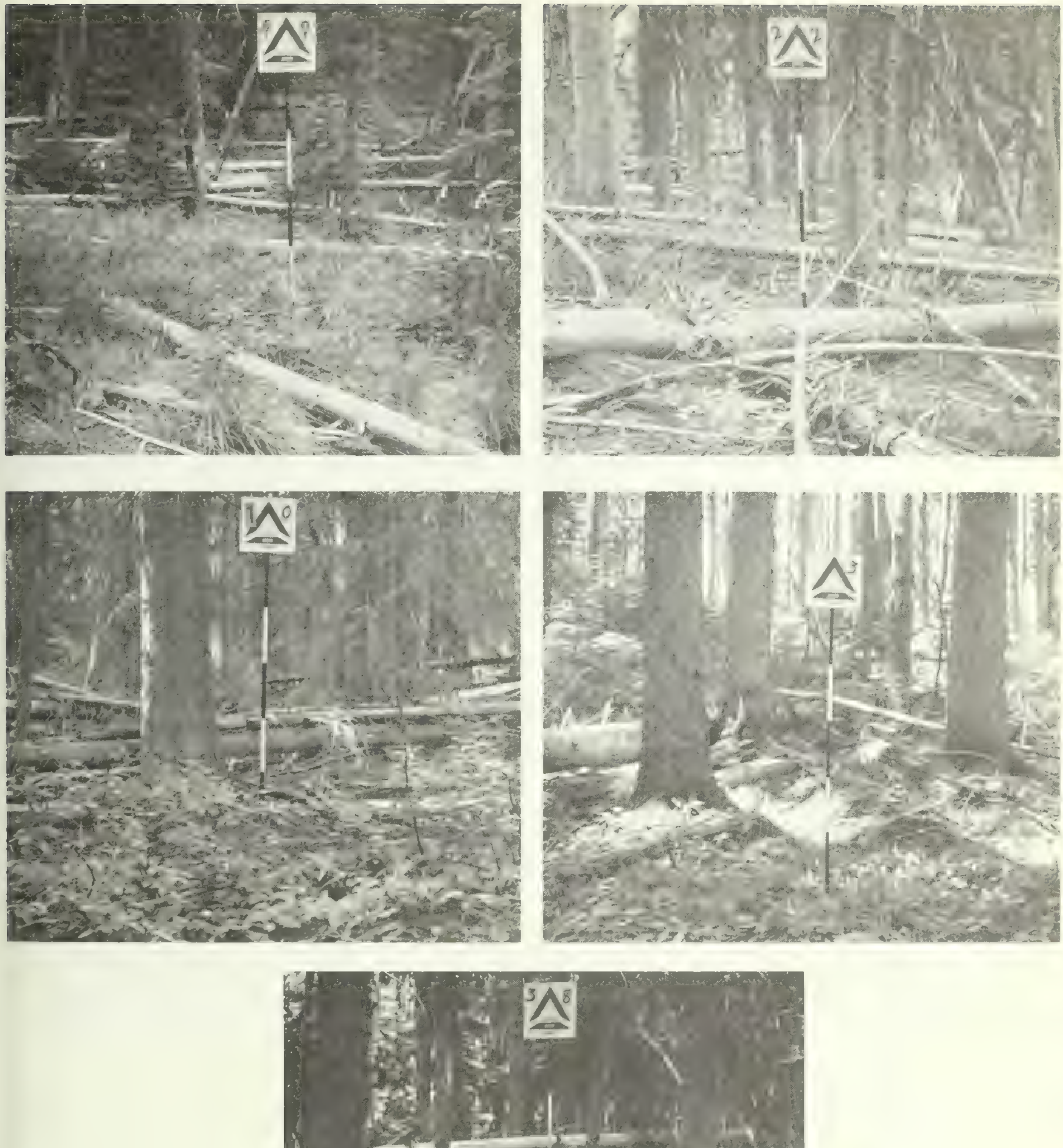


Fig. 13.--con.

Table 5.--*Fuel loadings by size class for 11 Group Eight and Nine stands*

Stand number	Age	Size class (inches) 0-1/4	1/4-1	1-3	3-6	6-10	10-20	20+	Total
	Years	- - - -	- - - -	- - - -	- - -	*Tons/acre*	- - - -	- - - -	- - - -
45	86	0.30	0.60	0.30	0.07	0	0	0	1.27
35	110	0.21	1.00	3.30	4.50	0	0	0	9.01
53	125	0.32	1.40	4.50	7.96	6.30	0	0	20.48
19	120	0.29	0.90	2.90	7.69	14.56	1.60	0	27.94
59	120	0.42	1.40	2.10	9.42	24.66	2.80	0	40.80
22	74	0.56	1.70	2.40	4.07	25.58	13.61	0	47.92
10	90	1.08	3.20	2.20	12.50	28.80	11.67	0	59.45
3	140	0.35	0.90	0.50	2.74	7.70	57.12	3.34	72.65
38	200	0.17	1.40	5.00	11.76	47.06	11.84	0	77.23
42	335	0.39	0.90	2.50	1.57	2.87	5.35	11.90	26.48
46	357	0.67	2.30	6.00	2.59	7.81	18.94	0	38.31

Frequently, the fuel load may be a result of a few very large diameter deadfalls. This situation is shown in stands 42 and 46 (fig. 14). Compare these stands to stands 19 and 59 (fig. 13 and table 5) for examples of comparable loadings with different size class distributions.

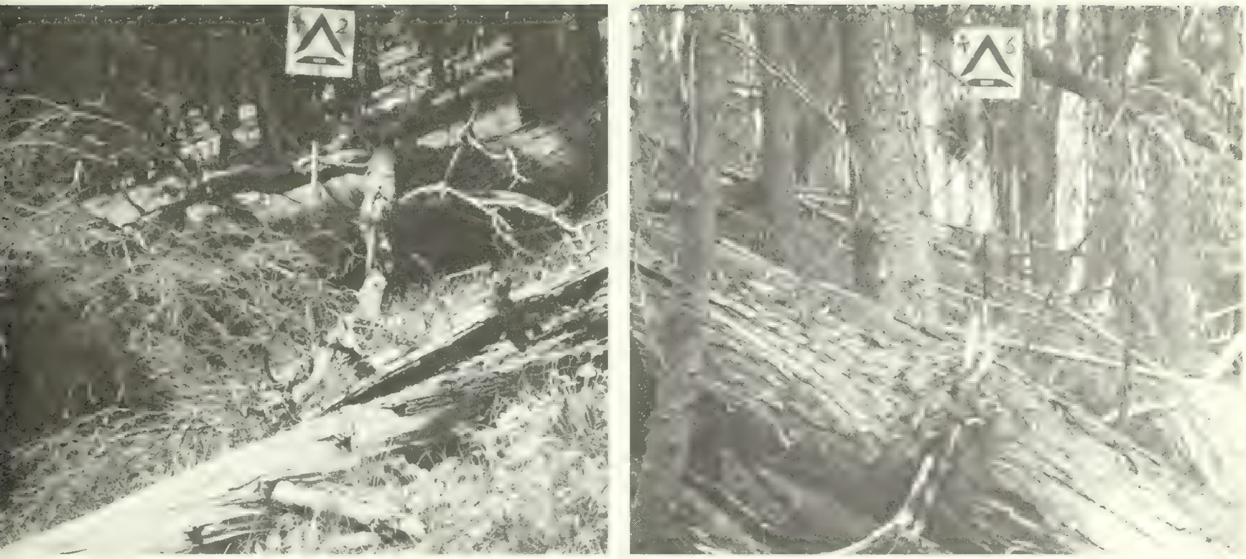


Figure 14.--Examples of heavy fuel loads that result from the presence of a few larger diameter deadfalls. Stand 42 is a Douglas-fir stand on an *Abies lasiocarpa/Menziesia ferruginea* h.t.-*Vaccinium globulare* phase (ABLA/MEFE-VAGL), subalpine fir/menziesia-blue huckleberry phase, and stand 46 is an Engelmann spruce/subalpine fir stand on an *Abies lasiocarpa/Menziesia ferruginea* h.t. (ABLA/MEFE: subalpine fir/menziesia. Total load and loading by size class and stand age are shown in table 5.

Role of Fire

Fire is less frequent in these subalpine habitat types than in previously discussed groups. Fire intensity can vary between light surface fires and stand-replacing burns. By opening the canopy and preparing a mineral seedbed, fire encourages shade-intolerant species.

Douglas-fir and lodgepole pine are the major components of seral stands. Locally, western larch and western white pine may be prominent in seral forests. Spruce and subalpine fir may be present in the fire-initiated stand, but they usually do not become prominent until later successional stages.

The mesic climate, dense stand habit, and long interval between fires in the subalpine forests lead to replacement burns. Apparently, fire is more frequent and less intense in the dry habitat types such as *Abies lasiocarpa/Xerophyllum tenax* h.t. (ABLA/XETE), subalpine fir/beargrass and less frequent, but more intense, in wet ones like *Abies lasiocarpa/Menziesia ferruginea* h.t. (ABLA/MEFE), subalpine fir/menziesia, *Abies lasiocarpa/Galium triflorum* h.t. (ABLA/GATR), subalpine fir/sweetscented bedstraw, *Abies lasiocarpa/Clintonia uniflora* h.t. (ABLA/CLUN), subalpine fir/queencup beadlily, and *Tsuga mertensiana/Menziesia ferruginea* h.t. (TSME/MEFE), mountain hemlock/menziesia (Arno 1976; Pfister and others 1977).

Fire maintains Group Eight and Nine forests in a seral status. If these forests had not been continuously disturbed by past fires, the climax spruce and fir would dominate most areas.

In the subalpine fir habitat types, revegetation of a burn will be determined by the composition of the preburn forest, the degree of fire damage, the amount of available seed, and the seedling survival. Fire favors intolerant trees, and repeated burns often promote one species.

Arno (1976) reported an average fire frequency of 24 years for habitat types belonging to Fire Groups Eight and Nine in his study in the Bitterroot Valley. In a more mesic forest type in Coram Experimental Forest, Sneck (1977) reported an average frequency of 140 years for these habitat types. Fire frequencies in Lolo National Forest stands probably fall within these extremes.

The effect of past fire suppression efforts has been to limit the spread of recent fires in these habitats. Over time, this will lead to abnormal fuel loadings and create a greater hazard than now exists.

Succession Diagram

Secondary succession in this group begins with a mixture of shrubs and herbs and possibly some conifer seedlings (fig. 15). Either shrubs or herbs may predominate, but neither is likely to be completely absent. Recurrent fires will maintain this community (fig. 15, No. 1).

Conifer seedlings become established over time without disturbance. Or, they germinate after a seedbed preparing burn (fig. 15, No. 2). The regeneration primarily consists of shade-intolerant trees, but the tolerant species may form a significant portion of the fire-initiated stand.

Young trees among plants in the undergrowth are less fire tolerant than surrounding plants. Therefore, a fire occurring soon after regeneration will return the vegetation to a shrub/herb mixture (fig. 15, No. 3) or thin the young trees (fig. 15, No. 4).

As the stand ages, trees are killed through suppression mortality and shade-tolerant species regenerate beneath the canopy. Downfall, standing snags, and fuel ladders increase the probability of an intense burn. A severe fire during the pole-size stage would recycle the site to the original secondary successional stage (fig. 15, No. 5).

Fire in a mature seral stand can have two results. Light-to-moderate intensity burns will control the succession of more tolerant trees and perpetuate a predominantly seral forest (fig. 15, No. 6). The tolerant species will probably never by eliminated from the seral stage, but their representation will be limited by periodic fires. A severe, stand-destroying fire will return the forest to the secondary successional stage of shrubs and herbs (fig. 15, No. 7). A new seral stand will be initiated from available seed.

Without periodic disturbance, the mature seral stand will progress into a forest of climax species. This requires decades, perhaps centuries, of uninterrupted succession since many intolerant species can live from 300 to 400 years. A climax forest can develop if the forest goes many years without burning. In theory this could happen, but it is unusual for habitat types in the lower subalpine group to escape burning for that long. A severe fire in the climax forest recycles the site to the early successional stage (fig. 15, No. 8).

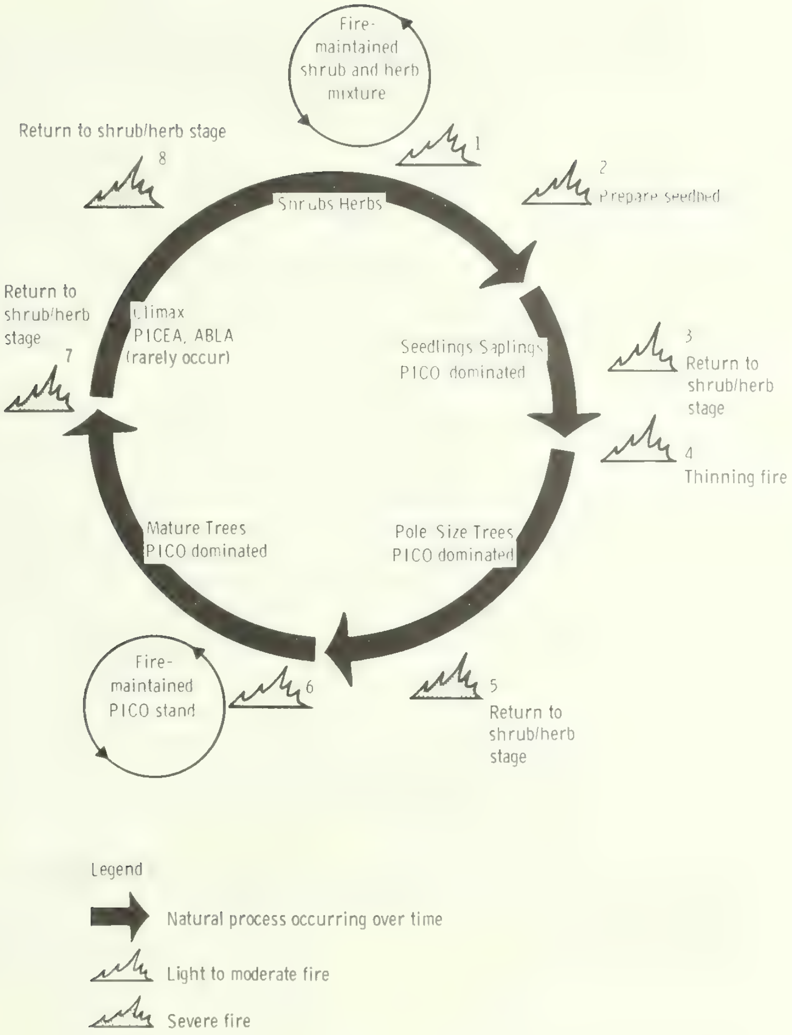


Figure 15.--Forest succession in Fire Groups Eight and Nine: lower subalpine habitat types.

Fire Management Considerations

There is a great potential for fire management programs designed to take advantage f fire's natural role in Group Eight and Nine habitat types. Fire may be compatible ith management objectives for many of these areas, hence, opportunities for reducing ire suppression costs often occur.

Fire protection is usually necessary during severe burning conditions, especially or areas where timber production is a management objective. At other times, fires ay be of low-to-moderate intensity and result in only moderate damage or no damage o overstory trees, despite the relatively low fire resistance of many of the species resent. The preceding statement refers to undisturbed natural stands. If slash is resent, unacceptable tree mortality can result under quite easy burning conditions.

Broadcast burning is an effective method for reducing slash hazard and for preparing seedbeds in clearcuts, but not in partial cuts. Timing of a burn is important. Group Eight and Nine habitats are so cool and moist that times when effective broadcast burns can be achieved are limited. The moisture content of the duff must be low enough to allow the fire to bare mineral soil over much of the area.

Burning slash in large windrows or piles often creates enough heat in the soil to inhibit plant growth for a long period of time. Consequently, windrows should be narrow and piles should be small when these methods are used.

Additional guidelines for fire use and silviculture in Group Eight and Nine stands are provided by Roe and others (1970). This reference should be consulted before planning fire use in these habitats.

Slash disposal plans should consider the need for some residues to remain on the site as discussed in the fire management considerations for Group Two habitats. Large logs left on the site also provide needed shade for successful seedling development.

The often complex structure of subalpine forests reflects their fire history. These forests are what they are partly because of past fires and partly because of their climate and soils. Their natural development has not, as a general rule, been affected by past fire suppression policies (Habeck and Mutch 1973). Management objectives for these habitat types are often oriented toward nonconsumptive use. These types usually have high watershed and big game sanctuary values. Many of the areas that contain these habitat types are roadless and are destined to remain so. Many are in designated wilderness areas. Consequently, the appropriate fire management policy is usually one that allows fire to play its natural role especially during the prefire and postfire seasons. Often this policy must be constrained because of air quality considerations and because of the occasional threat of long distance spotting or wind-driven crown fires.

FIRE GROUP TEN

COLD, MOIST UPPER SUBALPINE AND TIMBERLINE HABITAT TYPES

Habitat types - phase (Pfister and others 1977)	Ecoclass code (On and Losensky 1977)
Upper Subalpine	
Abies lasiocarpa/Luzula hitchcockii h.t.- *Vaccinium scoparium* phase (ABLA/LUHI-VASC), subalpine fir/smooth woodrush-grouse whhortleberry phase.	CS-6-831
Abies lasiocarpa/Luzula hitchcockii h.t.- *Menziesia ferruginea* phase (ABLA/LUHI-MEFE), subalpine fir/smooth woodrush-menziesia phase.	CS-6-832
Tsuga mertensiana/Luzula hitchcockii h.t.- *Vaccinium scoparium* phase (TSME/LUHI-VASC), mountain hemlock/smooth woodrush-grouse whortleberry phase.	CM-7-841
Tsuga mertensiana/Luzula hitchcockii h.t.- *Menziesia ferruginea* phase (TSME/LUHI-MEFE), mountain hemlock/smooth woodrush-menziesia phase.	CM-7-842

Timberline

Pinus albicaulis-Abies lasiocarpa h.t.'s (PIAL-ABLA h.t.'s), whitebark pine-subalpine fir.	CA-8-850
Larix lyallii-Abies lasiocarpa h.t.'s (LALY-ABLA h.t.'s), alpine larch-subalpine fir.	CA-8-860
Pinus albicaulis h.t.'s (PIAL h.t.'s), whitebark pine.	CA-8-870

Fire Group Ten is a collection of upper subalpine and timberline habitat types of the subalpine fir series. They cover 6 percent of the Lolo National Forest. Fuels are predominantly herb and shrub species and scattered downfall. Low-intensity lightning fires that have limited spread because of the lack of available fuels are characteristic of these habitats. Infrequent stand-destroying fires that enter from continuous forests of lower elevations have the greatest ecological effect. Recovery is slow because of the cold climate and short growing season.

Relationship of Major Tree Species to Fire

Picea engelmannii

Thin bark and low-growing canopy make spruce vulnerable to fire damage and to death. Fuels consist primarily of the undergrowth and scattered downfall, however, which limit fire spread and intensity. In addition, infrequent fires and the short burning season in these cold habitat types reduce the potential of fire damage.

Spruce is not an aggressive pioneer, but in the wetter Group Ten habitats, it is a persistent seral species. It is longer lived than *Abies* and functions as an important stand component. On dry sites, it is only a minor seral stand member. In the timberline habitats, it is more vigorous than *Abies* and can occur as a member of the climax stand.

Initial establishment and growth of seedlings are slow because of the cold climate in the higher elevations; so spruce may be slow to recover after fire.

Abies lasiocarpa

Subalpine fir has little resistance to fire and is readily killed. The vulnerability of subalpine fir to fire is counteracted in the timberline habitat types by the trees growing in small groups separated by rocks and open areas. Low ground fuel loadings on these sites limit fire spread and intensity.

In the *Abies lasiocarpa/Luzula hitchcockii* h.t. (ABLA/LUHI), subalpine fir/smooth woodrush, fir is the indicated climax. Its growth is quite slow, however, and 200 years may pass before it reaches dominant stand height (60 to 70 feet; 18 to 21 m). Fir trees seldom live more than 250 years because of wind and snow breakage or decay. Contributions of subalpine fir to the heavy fuel loadings increase the susceptibility of the longer-lived seral species, spruce, and whitebark pine to fire damage.

At timberline, fir is notably stunted having a shrublike structure or a shrubby skirt. It is slow to recover after fire.

Tsuga mertensiana

Mountain hemlock is another vulnerable species only slightly more fire resistant than subalpine fir. Its moderately thick bark affords some protection; but low-hanging branches, highly flammable needles, and a tendency to grow in dense groups make it vulnerable to fire damage. Fire injury makes it susceptible to rot.

Mountain hemlock is a climax species with marginal occurrence in the Lolo National Forest. Where moisture is ample (above 50 inches/yr; 127 cm/yr), it occupies a variety of slopes and exposures. In the subalpine fir series, mountain hemlock and subalpine fir are the only two trees capable of perpetuating themselves as climax dominants. Climax communities codominated by hemlock and fir are found in northwestern Montana.

Mountain hemlock grows in pure stands or in a mixture with a wide variety of associated species. The mountain hemlock habitat types are typically moist and fire occurrence is low. When these forests become dry enough to burn, however, they often burn very severely.

The ability for mountain hemlock to be a pioneer species apparently varies with locality. In northern California and southern Oregon, it has been reported to produce nearly pure, even-aged stands on old burn sites. In central Oregon, British Columbia, and Alaska it has invaded small openings, meadows, glacial moraines, and heather communities. It is an invader of burn sites in the montane taiga of the northern Rocky Mountains. Its absence, however, on recently disturbed areas in southeastern British Columbia suggests that it may not be a pioneer species everywhere.

Pinus albicaulis

Whitebark pine is an intolerant seral species that has been observed as a pioneer inhabiting burn sites. It is moderately fire resistant, but its dry, exposed habitat and open structure tend to reduce its vulnerability to fire. Whitebark pine may occur as small groups of trees especially near its lower elevational limit where it appears with subalpine fir and Engelmann spruce. The general impression of whitebark pine habitat types, however, is that of open stands where the undergrowth is predominantly continuous low shrubs, forbs, and grasses. Occasionally larger shrubs and stunted trees occur.

Fires burn with low-to-moderate intensity in the undergrowth. The low, ground-hugging crowns of associated conifers, however, provide a fuel ladder and the downfall in the vicinity of mature trees locally increases fire intensity and flame residence time. Many of the larger individual pines in the Lolo National Forest were killed by mountain pine beetle between 1909 and 1940 (Arno 1970). This has increased the potentia severity of fires in stands of whitebark pine. Despite the massive amounts of downfall, few severe fires have occurred, probably because of unfavorable burning conditions.

Intense wildfires starting in lower elevations can burn throughout the upper elevation forests to timberline. Although the open nature of a whitebark pine forest acts as a firebreak, many trees can be killed under these conditions. The most common fires are lightning fires that do not spread far nor do much damage.

Larix lyallii

Alpine larch is a thin-barked species easily damaged by fire. It is moderately fire-resistant, however, primarily because of its stand habit. It grows only on the highest elevations inhabiting rock faces, talus slopes, shallow soils, and moist, marshy sites. Alpine larch can grow in pure groves, in small groups, or as isolated individuals. At the lowest limits of its distribution, it may occur with subalpine fir, Engelmann spruce, and whitebark pine.

In the timberline zone, fire is a cause of tree mortality, but is less frequent and widespread than in contiguous forests below. Severe fires may enter the alpine larch stands from lower forests; however, they do not always adversely affect alpine larch stands. The severe Sundance Fire of 1967 swept the ridges of Roman Nose Mountain (Selkirk Mountains, Idaho) burning most of the whitebark pine and killing much of the spruce and fir in the cirques, but caused only minor damage to isolated stands of alpine larch. Sparse vegetation and rocky slopes curtail the intensity of fire in these areas.

When alpine larch grows with subalpine fir, Engelmann spruce, and whitebark pine, it is an intolerant seral species that dies out when overtopped by other conifers. Arno (1970) stated that fire allowed alpine larch to remain a major forest component with these species on Salmon Mountain, Idaho.

Forest Fuels

Fuel information for Group Ten habitat types of the Lolo National Forest is lacking. Data do exist, however, from the nearby Selway-Bitterroot Wilderness Area. Table 6 shows some of the Selway-Bitterroot data for two upper subalpine habitat types and one timberline habitat type that occur on the Lolo.

Table 6.--*Average fuel loadings for Group Ten stands*

Habitat type	Number of plots	Size class (inches)							Total	
		0-1/4	1/4-1	1-3	3-6	6-10	10-20	20+	woody	Duff
		Tons/acre								
ABLA/LUHI-VASC	80	0.16	0.69	0.24	0.66	3.26	2.78	0	7.79	7.23
ABLA/LUHI-MEFE	48	0.21	0.56	1.37	1.94	6.98	11.07	3.60	25.73	33.48
LALY-ABLA	25	0.10	0.26	0.13	0.37	1.97	4.84	3.28	10.95	11.23

The fuel loadings shown in table 6 are averages for all sampled stands rather than individual stand data presented for the other fire groups. Keep in mind that the standard deviation of table 6 values is often as great as the values themselves. Nonetheless, differences can be noticed. The drier *Abies lasiocarpa/Luzula hitchcockii* h.t.-*Vaccinium scoparium* phase (ABLA/LUHI-VASC), subalpine fir/smooth woodrush-grouse whortleberry phase habitats average about one-third the amount of down and dead woody material as the moist *Abies lasiocarpa/Luzula hitchcockii* h.t.-*Menziesia ferruginea* phase (ABLA/LUHI-MEFE), subalpine fir/smooth woodrush-menziesia phase types. Also notice the additional amount of fuel produced by the duff in these habitat types. Inspection of the original data sheets shows that much of the down woody material 3 inches (8 cm) and larger is rotten.

Role of Fire

Large fires are infrequent in Fire Group Ten. Lightning strikes often ignite fires but spread is limited by low fuel quantities and the wet weather that commonly accompanies thunderstorms.

The upper subalpine seral stand components are lodgepole pine, whitebark pine, and spruce. This subalpine habitat category is above the elevational limits of Douglas-fir, western larch, and western white pine; so spruce, fir, and mountain hemlock have a larger role in revegetating burned areas. Despite heavy fuel accumulations resulting from wind and snow damage, mountain pine beetle, and decay, severe fires are infrequent because of unfavorable burning conditions. Stand-destroying fires occur at intervals of 200 years or more. Lesser fires occur more frequently, but rarely do more than temporarily reduce the undergrowth and kill a few trees over a small area.

Timberline zone fires are not generally intense because of low fuel quantities, discontinuous fuels, and open-structured forest. Severe fires approaching timberline from contiguous forests below, however, occasionally destroy stands of alpine larch, whitebark pine, Engelmann spruce, and subalpine fir. Small area fires usually do not have the intensity or the spread potential to inflict much damage. Vegetation recovery is slow in the timberline zone because of the extremely short growing season and cold climate. Revegetation may take several decades and, in some cases, the effect of intense fires may be evident for centuries.

Vegetation growth and fuel accruement are slow in the higher elevations. Fire suppression policies have had little consequence on fire frequency or fuel loadings in these areas.

Succession Diagram

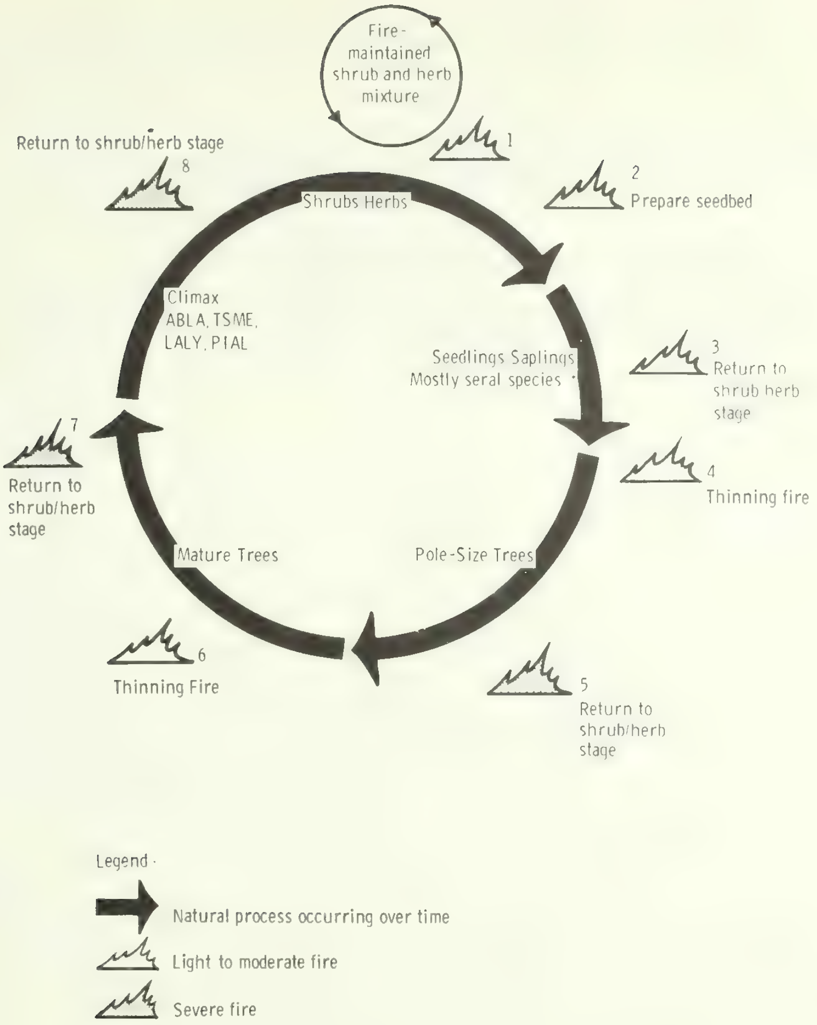
In Group Ten, secondary succession begins with a mixture of herbs and shrubs probably including some conifer seedlings (fig. 16). It is likely that herbaceous plants will dominate. Recurrent fire can maintain a predominantly herb/shrub community (fig. 16, No. 1).

Conifer seedlings can become established over time, but it is more likely that seedlings will germinate after a fire that reduces competition from the undergrowth species and prepares a mineral seedbed (fig. 16, No. 2). The seedling/sapling stage is composed of one or more of the major tree species since intolerant seral species, other than lodgepole, do not grow in the high elevations.

Small trees are less fire tolerant than the undergrowth species. A fire that occurs soon after regeneration will return the vegetation to a herb/shrub mixture (fig. 16, No. 3) or thin the regeneration (fig. 16, No. 4).

Pole-size trees are susceptible to fire damage because of their thin bark and low stature. A fire at this stage would kill the overstory and favor herb and shrub species (fig. 16, No. 5). It would be uncommon, however, for one fire to regenerate a Group Ten stand a second to appear when the trees are pole size. Fire frequencies are not usually so high, nor are sufficient fuels available so soon after stand replacement.

As the stand ages, trees are killed through suppression, snow/wind damage, insects, or diseases. Fire can have two effects in the mature stand. Light-to-moderate burns will thin the trees (fig. 16, No. 6) and prepare a seedbed for conifer regeneration to grow beneath the protection of the overstory. A severe fire, that probably would enter from lower elevations and more continuous fuels, will kill the overstory component and recycle the site to the herb/shrub stage (fig. 16, No. 7).



* Seral species vary with the habitat type. Generally they are lodgepole pine, Douglas-fir, western larch, and western white pine. Whitebark pine and alpine larch may act as seral species. Subalpine fir and mountain hemlock may occur in the seral stages of succession, but their representation will be limited by periodic fires.

Figure 16.--Forest succession in Fire Group Ten: upper subalpine and timberline habitat types.

Without disturbance, the mature trees will progress into a climax stand. This advance successional stage requires decades, possibly two or three centuries. Low-to-moderate fires rarely have a significant impact on a mature stand because of the open structure and lack of woody fuels; however, severe fires that enter the crowns and kill the cambium of trees return the site to the early successional stages (fig. 16, No. 8).

Fire Management Considerations

Timber production is rarely an important management objective in Group Ten habitat types. Most of these areas are managed as watersheds and game sanctuaries. Most are roadless and many are in wilderness areas. Fire is an infrequent visitor and, when it does occur, damage, in terms of management objectives, is generally slight. These sites are often fragile and can easily be damaged by modern, mechanized fire-fighting equipment.

The primary fire management consideration for Group Ten habitats should be the development of fire management prescriptions that allow fire to more nearly play its natural role.

FIRE GROUP ELEVEN

WARM, MOIST GRAND FIR, WESTERN REDCEDAR, AND WESTERN HEMLOCK HABITAT TYPES

Habitat type - phase (Pfister and others 1977)	Ecoclass code (On and Losensky 1977)
Abies grandis/Xerophyllum tenax h.t. (ABGR/XETE), grand fir/beargrass.	CG-3-510
Abies grandis/Clintonia uniflora h.t.-*Clintonia uniflora* phase (ABGR/CLUN-CLUN), grand fir/queencup beadlily-queencup beadlily phase.	CG-5-521
Abies grandis/Clintonia uniflora h.t.-*Xerophyllum tenax* phase (ABGR/CLUN-XETE), grand fir/queencup beadlily-beargrass phase.	CG-5-523
Thuja plicata/Clintonia uniflora h.t.-*Clintonia uniflora* (THPL/CLUN-CLUN), western redcedar/queencup beadlily-queencup beadlily phase.	CC-5-531
Thuja plicata/Clintonia uniflora h.t.-*Aralia nudicaulis* phase (THPL/CLUN-ARNU), western redcedar/queencup beadlily-wild sarsaparilla phase.	CC-5-532
Thuja plicata/Clintonia uniflora h.t.-*Menziesia ferruginea* phase (THPL/CLUN-MEFE), western redcedar/queencup beadlily-menziesia phase.	CC-5-533
Thuja plicata/Oplopanax horridum h.t. (THPL/OPHO), western redcedar/devil's club.	CC-7-550
Tsuga heterophylla/Clintonia uniflora h.t.-*Aralia nudicaulis* phase (TSHE/CLUN-ARNU), western hemlock/queencup beadlily-wild sarsaparilla phase.	CH-4-572

This group is a collection of warm moist habitat types, occurring on moist valley bottoms, benches, ravines, and protected exposures. In these moist habitats, fires are infrequent and often severe. Group Eleven habitat types make up 13 percent of the Lolo National Forest. The grand fir (*Abies grandis*) habitats are the driest in this group.

Relationship of Major Tree Species to Fire

Abies grandis

An individual, mature grand fir is moderately fire resistant primarily because of its moderately thick bark; however, its low and dense branching habit, highly flammable foliage, heavy lichen growth, shallow root system, and dense stand habit make it susceptible to fire injury, and death.

Fire resistance is strongly influenced by habitat. Grand fir succumbs to ground fire when the duff burns deeply enough to injure the root system. On relatively dry mountain slopes where grand fir grows, the deeper root system, thinner duff fuels, and more open stand structure make fir less vulnerable. Decay often enters through fire wounds.

Grand fir is a shade-tolerant species in all associations in which it grows. When it grows with *Thuja* and *Tsuga*, it occurs as a subordinate to these more tolerant species. Douglas-fir is a major component of seral stands in grand fir habitats. Western larch, lodgepole pine, spruce, subalpine fir, ponderosa pine, and western white pine are seral dominants or components of mixed stands that out-compete grand fir during the initial stages of succession.

Grand fir is not an aggressive pioneer. Seedling mortality is high because of biotic agents in the wet seasons and because of drought and insolation in late summer. Initial survival and growth are favored by moderate shade. In partial shade, fir can form a considerable part of the dominant reproduction, but, in full sun conditions, it is subordinate to faster growing intolerant species. Early growth is determined more by the amount of competition than site quality.

Tsuga heterophylla

Western hemlock is vulnerable to fire because of its relatively thin bark, exposed roots, lichen growth, highly flammable foliage, low branching habit, and dense stand habit; however, its cool, mesic habitat offers protection against all but the most severe wildfires. Fungi enter through fire scars and compound fire-caused damage.

Associated seral species in the western hemlock habitat types are Douglas-fir, western larch, spruce, lodgepole pine, and western white pine. Grand fir, subalpine fir, and western redcedar are either minor seral or minor climax components.

Thuja can maintain itself indefinitely as a minor climax species in the *Tsuga* series because of its shade tolerance, longevity, and vegetative reproduction ability.

Hemlock is a prolific seeder at an early age. It can be an aggressive pioneer because of its quick growth in full overhead light and its ability to survive under a wide variety of seedbed conditions. The light, winged seed can be carried a considerable distance, but usually falls within a few hundred feet of the parent tree. Germination under forest conditions is excellent on a wide variety of seedbeds, including stumps and logs, as long as adequate moisture is available.

Thuja plicata

Western redcedar is only moderately resistant to fire because of its thin bark, shallow root system, and moderately low and dense branching habit. Resistance is enhanced by the mesic environment which can act as a firebreak to low-and-moderate intensity fires.

Seral stands are dominated by Douglas-fir, western larch, and spruce. Minor seral components are lodgepole pine, western white pine, grand fir, and subalpine fir. The true firs may also assume roles as minor climax components. Hemlock appears as a subordinate species to *Tsuga* or as a coclimax.

Cedar is not an aggressive pioneer species because the succulent seedling is susceptible to high soil temperatures and is slow in root development. Seedling survival on burned or unburned mineral soil is best under partial shade. Rapid drying of the duff and the small size of the seed account for the poor germination on duff; however, cedar is a prodigious seed producer, a characteristic that enables it to enter pioneer communities at an early stage.

Western redcedar is a shade-tolerant species. It commonly grows in association with *Tsuga*. Dense stands of cedar and associates exclude most subordinate vegetation; however, a wide variety of undergrowth species may appear when stands are at all open.

Associated Conifers

Douglas-fir, western larch, lodgepole pine, ponderosa pine, western white pine, subalpine fir, and spruce are all associates in Group Eleven habitat types. They have been discussed in detail and so will not be covered in this chapter. In grand fir, western redcedar, and western hemlock habitat types these trees occur as minor or major seral species or as minor climax components (appendix C). The pioneer and seral species in this group are fire dependent.

Forest Fuels

Light fuel loadings are rare in Group Eleven stands on the Lolo National Forest. The range of loadings likely to be found is from 15 tons/acre to over 40 tons/acre (3.4 kg/m^2 to 9.0 kg/m^2). The average fuel load is about 25 tons/acre (5.6 kg/m^2). Most of the fuel results from accumulated deadfall and occasional natural thinning. Because of the heavy grand fir and cedar component of Group Eleven stands, a relatively heavy load of twigs and small branchwood is included in the fuel load. The large material, which accounts for about 75 percent of the fuel load, is often rotten.

Figure 17 shows examples of different levels of fuel loading. Reference to table 7 shows that the amount of small dead fuels is fairly constant while the amount of 10- to 20-inch fuels actually determines the load.

igure 17.--Examples of fuel loadings in Group Eleven stands. All are grand fir/western larch/Douglas-fir stands on an *Abies grandis/Clintonia uniflora* h.t.-*Clintonia uniflora* phase (ABGR/CLUN-CLUN), grand fir/queencup beadlily-queencup beadlily phase. Total load, loading by size class, and stand age are given in table 7.

Table 7.--*Fuel loadings by size class for five Group Eleven stands*

Stand number	Age	Size class (inches)							
		0-1/4	1/4-1	1-3	3-6	6-10	10-20	20+	Total
	Years	*Tons/acre*							
16	120	0.89	1.70	2.10	3.28	6.07	2.20	0	16.24
15	85	0.62	1.30	3.30	3.60	3.18	8.53	0	20.53
65	118	0.45	1.90	3.60	7.18	10.79	0	0	27.42
25	114	1.14	2.20	5.50	0.64	6.33	17.13	2.58	35.52
66	280	0.62	1.60	1.20	3.49	4.40	26.72	0	38.03

Role of Fire

Fire is less frequent in these habitat types than in other fire groups because of the mesic to hydric environments. In dense stands, scarcely any undergrowth is present and duff and heavier fuels are cool and usually moist. These conditions do not encoura fire intensity nor fire spread.

There are two distinct effects and behavior of fire in Group Eleven. First, the mesic site may act as a firebreak to ground fires. A fire may burn into the edges of a stand, possibly scarring some trees, but it will usually die out when it reaches the moist duff layer.

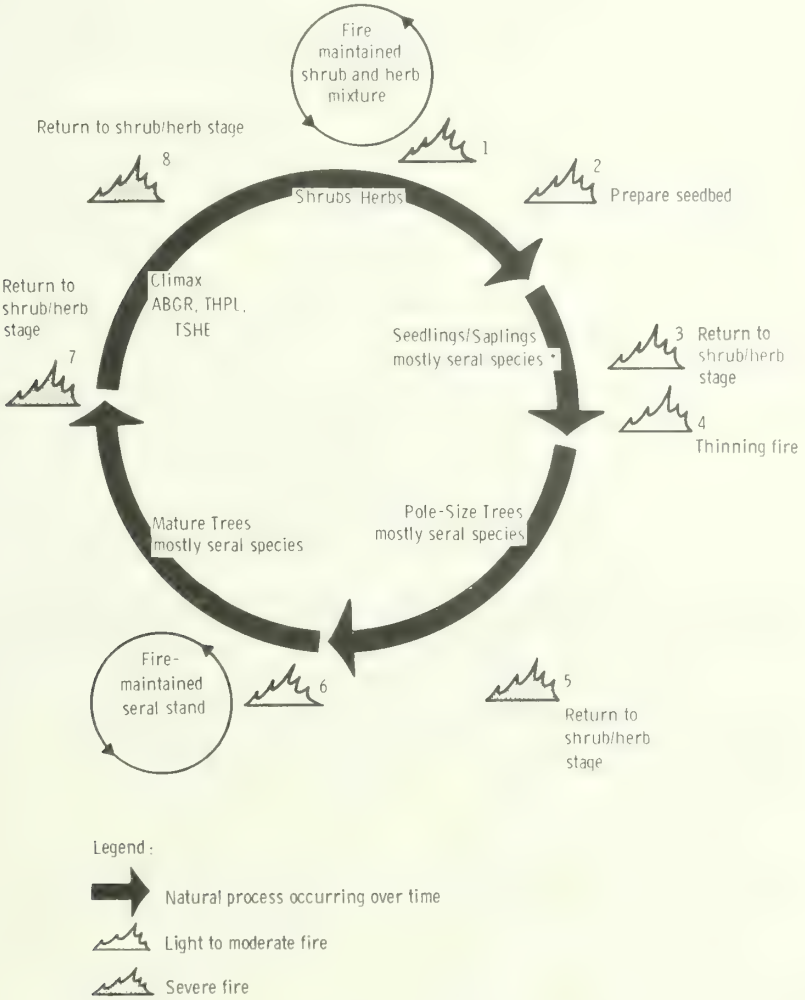
Secondly, plant productivity in Group Eleven is high; so heavy fuels accumulate. These moist habitat types do not frequently burn, but, when they do, the heavy fuels make fires intense. A stand-replacing burn results; so the site reverts to pioneer plants.

Climax and seral species invade a fresh burn simultaneously when both seed sources are available. The seral trees quickly out-compete the climax species and reduce them to the role of a slow-growing understory. Douglas-fir is a common seral tree; but wher fires follow one another within a few decades, lodgepole pine, western larch, and white pine stands increase. Frequent fires could maintain grand fir, western hemlock, and western redcedar habitat types as seral forests.

Fire history investigations have shown that severe, stand-replacing fires occurre anywhere from 150 to more than 500 years. Moderate-to-light ground fires occur anywhere from 50 to 100 years. Often fires that died out in the moist grand fir, western redcedar, and western hemlock habitat types devastated the surrounding forests.

Succession Diagram

In group Eleven, secondary succession begins with a mixture of shrubs and herbs and possibly some conifer seedlings (fig. 18). Frequent fires occurring at this stage maintain the undergrowth community (fig. 18, No. 1). With time, conifer seedlings become established. Seedling establishment will also take place following a seedbed preparing burn (fig. 18, No. 2). The regeneration usually is composed of intolerant trees, but *Abies, Thuja,* and *Tsuga* may form a significant portion of the fire-initiated stand.


Fire maintained shrub and herb mixture
1
2
Prepare seedbed
Return to shrub/herb stage
8
Shrubs Herbs
Climax ABGR, THPL, TSHE
Return to shrub/herb stage
7
Seedlings/Saplings mostly seral species *
3
Return to shrub/herb stage
4
Thinning fire
Mature Trees mostly seral species
Pole-Size Trees mostly seral species
Fire-maintained seral stand
6
5
Return to shrub/herb stage
Legend:
Natural process occurring over time
Light to moderate fire
Severe fire

* Seral species vary with the habitat type. Generally they are ponderosa pine, lodgepole pine, Douglas-fir, western larch, western white pine, subalpine fir, and spruce. Grand fir, western redcedar, and western hemlock may occur in seral stages, but their representation will be limited by periodic fires.

Figure 18.--Forest succession in Fire Group Eleven: grand fir, western redcedar, and western hemlock habitat types.

A light-to-moderate fire occurring during the early seral stages would kill the young conifers and return the site to a shrub and herb community (fig. 18, No. 3). If the burn were incomplete, the fire would act as a thinning agent (fig. 18, No. 4).

Group Eleven sites are highly productive. Dense vegetation in stands of pole-siz trees promote severe fires (fig. 18, No. 5); however, these are moist sites, and stand-destroying fires are not common during this stage.

Fire in the mature seral stand can have two results. First, light-to-moderate fires would maintain fire-resistant, intolerant species at the expense of less resista trees (fig. 18, No. 6). Grand fir, western redcedar, and western hemlock may not be completely eliminated, but their representation will be limited. Second, a severe, stand-destroying fire will return the forest to the early secondary stages of a shrub- and herb-dominated mixture (fig. 18, No. 7). A new conifer stand will develop from available seed. The frequency of fires may promote one seral tree species, such as western larch or western white pine, and thereby create a nearly pure stand.

Short intervals between fires in the mesic habitats of Group Eleven are not usual, so the seral stand will progress to the climax forest over time. A forest of climax species takes centuries of uninterrupted succession in order to develop. It may be 300 to 400 years before the intolerant trees become subordinate to the climax component

A severe fire in the climax stand (fig. 18, No. 8) will cause the site to revert to a shrub and herb mixture that probably will include some conifer seedlings.

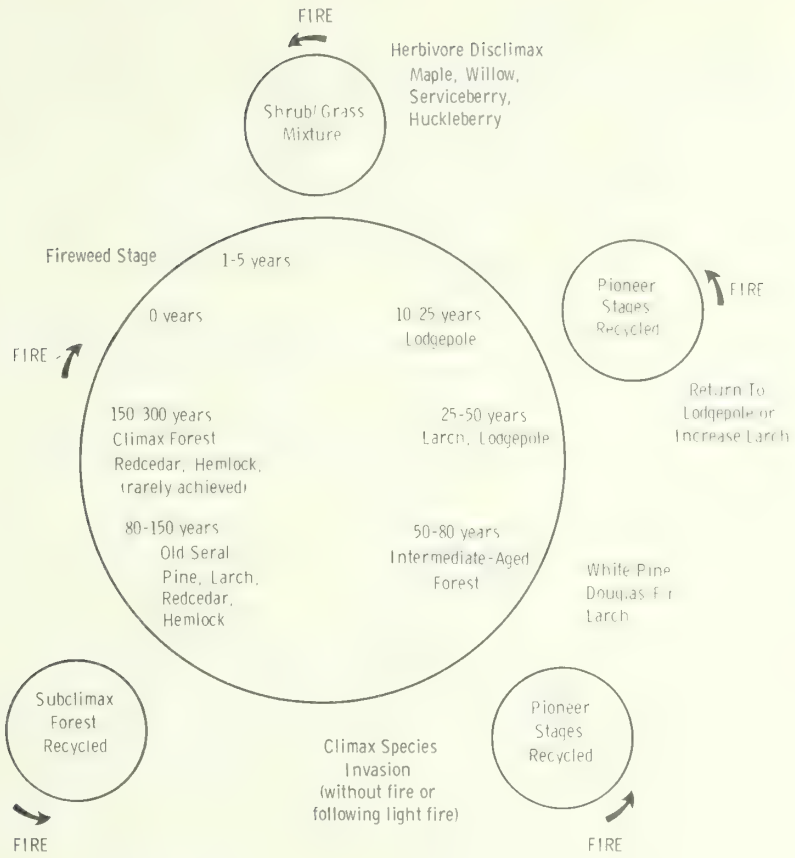
The successional development and fire disturbance for cedar-hemlock and grand fir forests have been illustrated by Habeck (1970) and Antos (personal communication). Their diagrams are shown in figures 19 and 20, respectively.

Fire Management Considerations

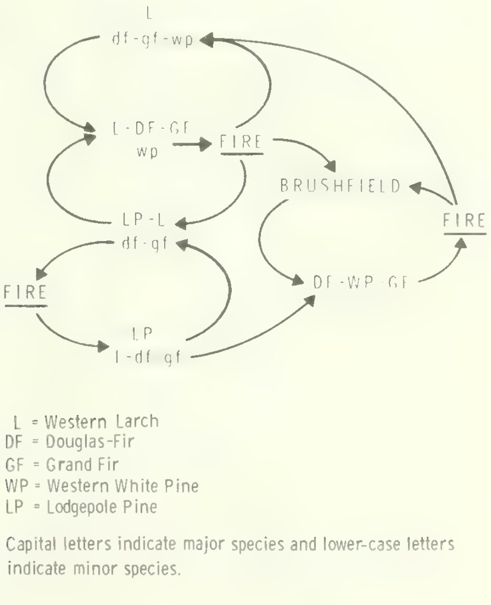
Fire Group Eleven habitat types are often highly productive timber growing sites. Where timber management is the objective, and even-aged silviculture is applied to fav seral species, such as ponderosa pine and western larch, broadcast fire can be used to reduce slash hazard and prepare seedbed after harvest operations. Broadcast burning i inappropriate when partial cutting leaves heat-susceptible grand fir and associated species in the overstory. The use of fire for site preparation will usually result in increased spring and summer browse for big game in addition to successful regeneration of seral tree species.

Moisture conditions are usually high enough in Group Eleven habitat types to prevent serious heat damage by low intensity wildfire, especially in old stands. Low intensity or smoldering surface fires may cause some heat damage to grand fir, hemlock, cedar, subalpine fir, and spruce. Surface fires often scar the base of these species creating favorable entry points for decay organisms. During periods of drought, the large, often rotten forest floor fuels can dry out. Fires that start under low fuel moisture conditions can be intense and can result in death for almost the entire stand Summertime moisture conditions in young stands are not nearly as high as in older stan Consequently, the effects of fire are often more severe than they are in older stands.

Group Eleven habitats are often found between streams and forest roads in western Montana. Consequently, roadside fuel reduction activities often are concentrated in these habitats. Such programs should take into account the need for retaining some large woody material both for maintenance of site quality and for woodpecker food supp Also, snags and snag patches should be retained for their value as nest trees.



gure 19.--Successional development scheme and fire disturbance recycles in the upland cedar-hemlock forests on the Lake McDonald area, Glacier National Park (after Habeck 1970).



gure 20.--Generalized successional patterns following fire on grand fir sites within Swan Valley, Montana (Antos 1977).

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APPENDIX A

APPENDIX A

Forest Habitat Types Occurring in the Lolo National Forest

ADP code[1]	Abbreviation	Habitat types and phases	
		Scientific names	Common names
100		*PINUS PONDEROSA* CLIMAX SERIES	
130	PIPO/AGSP	*Pinus ponderosa/Agropyron spicatum* h.t.	ponderosa pine/bluebunc wheatgrass
140	PIPO/FEID h.t.	*Pinus ponderosa/Festuca idahoensis* h.t.	ponderosa pine/Idaho fe
141	FEID phase	*Festuca idahoensis* phase	Idaho fescue phase
142	FESC phase	*Festuca scabrella* phase	rough fescue phase
160	PIPO/PUTR h.t.	*Pinus ponderosa/Purshia tridentata* h.t.	ponderosa pine/bitterbr
161	AGSP phase	*Agropyron spicatum* phase	bluebunch wheatgrass p
162	Feid phase	*Festuca idahoensis* phase	Idaho fescue phase
170	PIPO/SYAL h.t.	*Pinus ponderosa/Symphoricarpos albus* h.t.	ponderosa pine/snowberr
171	SYAL phase	*Symphoricarpos albus* phase	snowberry phase
200		*PSEUDOTSUGA MENZIESII* CLIMAX SERIES	
210	PSME/AGSP h.t.	*Pseudotsuga menziesii/Agropron spicatum* h.t.	Douglas-fir/bluebunch wheatgrass
220	PSME/FEID h.t.	*Pseudotsuga menziesii/Festuca idahoensis* h.t.	Douglas-fir/Idaho fescue
230	PSME/FESC h.t.	*Pseudotsuga menziesii/Festuca scabrella* h.t.	Douglas-fir/rough fescue
250	PSME/VACA h.t.	*Pseudotsuga menziesii/Vaccinium caespitosum* h.t.	Douglas-fir/dwarf huckleberry
260	PSME/PHMA h.t.	*Pseudotsuga menziesii/Physocarpos malvaceus* h.t.	Douglas-fir/ninebark
261	PHMA phase	*Physocarpos malvaceus* phase	ninebark phase
262	CARU phase	*Calamagrostis rubescens* phase	pinegrass phase
280	PSME/VAGL h.t.	*Pseudotsuga menziesii/Vaccinium globulare* h.t.	Douglas-fir/blue huckleberry
281	VAGL phase	*Vaccinium globulare* phase	blue huckleberry phase
282	ARUV phase	*Arctostaphylos uva-ursi* phase	kinnikinnick phase
283	XETE phase	*Xerophyllum tenax* phase	beargrass phase
290	PSME/LIBO h.t.	*Pseudotsuga menziesii/Linnaea borealis* h.t.	Douglas-fir/twinflower
291	SYAL phase	*Symphoricarpos albus* phase	snowberry phase
292	CARU phase	*Calamagrostis rubescens* phase	pinegrass phase
293	VAGL phase	*Vaccinium globulare* phase	blue huckleberry phase
310	PSME/SYAL h.t.	*Pseudotsuga menziesii/Symphoricarpos albus* h.t.	Douglas-fir/snowberry
311	AGSP phase	*Agropyron spicatum* phase	bluebunch wheatgrass p
312	CARU phase	*Calamagrostis rubescens* phase	pinegrass phase
313	SYAL phase	*Symphoricarpos albus* phase	snowberry phase
320	PSME/CARU h.t.	*Pseudotsuga menziesii/Calamagrostis rubescens* h.t.	Douglas-fir/pinegrass
321	AGSP phase	*Agropyron spicatum* phase	bluebunch wheatgrass p
322	ARVU phase	*Arctostaphylos uva-ursi* phase	kinikinnick phase
323	CARU phase	*Calamagrostis rubescens* phase	pinegrass phase
324	PIPO phase	*Pinus ponderosa* phase	ponderosa pine phase
330	PSME/CAGE h.t.	*Pseudotsuga menziesii/Carex geyeri* h.t.	Douglas-fir/elk sedge
340	PSME/SPBE h.t.	*Pseudotsuga menziesii/Spiraea betulifolia* h.t.	Douglas-fir/white spira

(continued)

	Habitat types and phases	
Abbreviation	Scientific names	Common names
	PICEA CLIMAX SERIES	
PICEA/GATR h.t.	*Picea/Galium triflorum* h.t.	spruce/sweetscented bedstraw
PICEA/LIBO h.t.	*Picea/Linnaea borealis* h.t.	spruce/twinflower
	ABIES GRANDIS CLIMAX SERIES	
ABGR/XETE h.t.	*Abies grandis/Xerophyllum tenax* h.t.	grand fir/beargrass
ABGR/CLUN h.t.	*Abies grandis/Clintonia uniflora* h.t.	grand fir/queencup beadlily
CLUN phase	*Clintonia uniflora* phase	queencup beadlily phase
XETE phase	*Xerophyllum tenax* phase	beargrass phase
	THUJA PLICATA CLIMAX SERIES	
THPL/CLUN h.t.	*Thuja plicata/Clintonia uniflora* h.t.	western redcedar/queencup beadlily
CLUN phase	*Clintonia uniflora* phase	queencup beadlily phase
ARNU phase	*Aralia nudicaulis* phase	wild sarsaparilla phase
MEFE phase	*Menziesia ferruginea* phase	menziesia phase
THPL/OPHO h.t.	*Thuja plicata/Oplopanax horridum* h.t.	western redcedar/devil's club
	TSUGA HETEROPHYLLA CLIMAX SERIES	
TSHE/CLUN h.t.	*Tsuga heterophylla/Clintonia uniflora* h.t.	western hemlock/queencup beadlily
ARNU phase	*Aralia nudicaulis* phase	wild sarsaparilla phase
	ABIES LASIOCARPA CLIMAX SERIES	
	lower subalpine h.t.'s	
ABLA/OPHO h.t.	*Abies lasiocarpa/Oplopanax horridum* h.t.	subalpine fir/devil's club
ABLA/CLUN h.t.	*Abies lasiocarpa/Clintonia uniflora* h.t.	subalpine fir/queencup beadlily
CLUN phase	*Clintonia uniflora* phase	queencup beadlily phase
ARNU phase	*Aralia nudicaulis* phase	wild sarsaparilla phase
VACA phase	*Vaccinium caespitosum* phase	dwarf huckleberry phase
XETE phase	*Xerophyllum tenax* phase	beargrass phase
MEFE phase	*Menziesia ferruginea* phase	menziesia phase
ABLA/GATR h.t.	*Abies lasiocarpa/Galium triflorum* h.t.	subalpine fir/sweetscented bedstraw
ABLA/VACA h.t.	*Abies lasiocarpa/Vaccinium caespitosum* h.t.	subalpine fir/dwarf huckleberry
ABLA/CACA h.t.	*Abies lasiocarpa/Calamagrostis canadensis* h.t.	subalpine fir/bluejoint
CACA phase	*Calamagrostis canadensis* phase	bluejoint phase
GATR phase	*Galium triflorum* phase	sweetscented bedstraw phase
VACA phase	*Vaccinium caespitosum* phase	dwarf huckleberry phase
ABLA/LIBO h.t.	*Abies lasiocarpa/Linnaea borealis* h.t.	subalpine fir/twinflower
LIBO	*Linnaea borealis* phase	twinflower phase
XETE phase	*Xerophyllum tenax* phase	beargrass phase
VASC phase	*Vaccinium scoparium* phase	grouse whortleberry phase
ABLA/MEFE h.t.	*Abies lasiocarpa/Menziesia ferruginea* h.t.	subalpine fir/menziesia

(continued)

ADP code[1]	Abbreviation	Habitat types and phases	
		Scientific names	Common names
680	TSME/MEFE h.t.	*Tsuga mertensiana/Menziesia ferruginea* h.t.	mountain hemlock/menzi
690	ABLA/XETE h.t.	*Abies lasiocarpa/Xerophyllum tenax* h.t.	subalpine fir/beargras
691	VAGL phase	*Vaccinium globulare* phase	blue huckleberry phas
692	VASC phase	*Vaccinium scoparium* phase	grouse whortleberry p
710	TSME/XETE h.t.	*Tsuga mertensiana/Xerophyllum tenax* h.t.	mountain hemlock/bearg
720	ABLA/VAGL h.t.	*Abies lasiocarpa/Vaccinium globulare* h.t.	subalpine fir/blue huckleberry
800		Upper subalpine h.t.'s	
830	ABLA/LUHI	*Abies lasiocarpa/Luzula hitchcockii* h.t.	subalpine fir/smooth woodrush
831	VASC phase	*Vaccinium scoparium* phase	grouse whortleberry p
832	MEFE phase	*Menziesia ferruginea* phase	menziesia phase
840	TSME/LUHI h.t.	*Tsuga mertensiana/Luzula hitchockii* h.t.	mountain hemlock/smoot woodrush
841	VASC phase	*Vaccinium scoparium* phase	grouse whortleberry p
842	MEFE phase	*Menziesia ferruginea* phase	menziesia phase
890		Timberline h.t.'s	
850	PIAL-ABLA h.t.'s	*Pinus albicaulis-Abies lasiocarpa* h.t.'s	whitebark pine-subalpi
860	LALY-ABLA h.t.'s	*Larix lyallii-Abies lasiocarpa* h.t.'s	alpine larch-subalpine
870	PIAL h.t.'s	*Pinus albicaulis* h.t.'s	whitebark pine

---

[1] Automatic data processing codes for National Forest System use.

APPENDIX B

APPENDIX B

Ecoclass Code for Lolo National Forest Habitat Types

(On and Losensky 1977)

The Ecoclass System was developed to provide a hierarchial approach to vegetation for all levels of land planning. The following example illustrates the meaning of the code.

CP-1-162

Formation	Association	Subgroup	Habitat type - phase
C(conifer)	P(ponderosa pine)	1(warm, dry)	162 (PIPO/PUTR-FEID)

The ecoclass code symbols used in the ecoclass code are defined:

Formation

C-Coniferous forest areas, stands dominated by conifers even though hardwoods may be present; climax coniferous forest.

Association

A-Alpine, open forest parks of subalpine fir, whitebark pine, mountain hemlock, alpine larch.

C-Western redcedar as the climax dominant

D-Douglas-fir as the climax dominant

E-Engelmann spruce as the climax dominant

G-Grand fir as tha climax dominant

H-Western hemlock as the climax dominant

P-Ponderosa pine as the climax dominant

S-Subalpine fir as the climax dominant

Subgroup

1-Warm, dry

2-Moderately warm, dry

3-Moderately cool, dry

4-Cool, moderately dry

5-Moderately cool, moist

6-Cool, moist

7-Wet

8-Cold, moderately dry

Habitat type and phase

Refer to Habitat Types of Montana (Pfister and others 1977), table 1, pages 6 and 7 for meaning of the data processing code.

APPENDIX C

APPENDIX C

Distribution of Tree Species in Lolo National Forest Habitat Types Showing Their Dynamic Status as Interpreted from Sample Stand Data (after Pfister and others 1977)

Fire Group	Habitat type/ phase	JUSC	PIPO	PSME	PICO	LAOC	PICEA	ABGR	PIMO	THPL	TSHE	ABLA	TSME	PIAL	LALY
1	PIPO/AGSP	(c)	C	a	.	.	.	.	.	.	.	.	.	.	.
	PIPO/FEID, FEID	a	C	a	.	.	.	.	.	.	.	.	.	.	.
	PIPO/FEID, FESC	a	C	a	.	.	.	.	.	.	.	.	.	.	.
	PIPO/PUTR, AGSP	a	C	a	.	.	.	.	.	.	.	.	.	.	.
	PIPO/PUTR, FEID	(c)	C	a	.	.	.	.	.	.	.	.	.	.	.
	PIPO/SYAL, SYAL	a	C	a	.	.	.	.	.	.	.	.	.	.	.
2	PSME/AGSP	(c)	C	C	.	.	.	.	.	.	.	.	.	.	.
	PSME/FESC	a	C	C	.	.	.	.	.	.	.	.	.	.	.
	PSME/PHMA, CARU	.	S	C	a	a	.	.	.	.	.	.	.	.	.
	PSME/SYAL, AGSP	.	S	C	.	.	.	.	.	.	.	.	.	.	.
	PSME/CARU, AGSP	.	S	C	.	.	.	.	.	.	.	.	.	.	.
	PSME/CARU, PIPO	.	S	C	.	.	.	.	.	.	.	.	.	.	.
	PSME/SPBE	.	(S)	C	a	a	.	.	.	.	.	.	.	.	.
3	PSME/FEID	a	a	C	.	.	.	.	.	.	.	.	.	.	.
	PSME/VACA	.	(S)	C	S	(S)	a	.	.	.	.	a	.	.	.
	PSME/PHMA, PHMA	.	(s)	C	(s)	(s)	.	a	.	.	.	.	.	.	.
	PSME/VAGL, VAGL	.	(s)	C	S	(s)	a	.	.	.	.	a	.	a	.
	PSME/VAGL, ARUV	.	S	C	(s)	(s)	.	a	.	.	.	.	.	.	.
	PSME/VAGL, XETE	.	(s)	C	S	(S)	.	a	.	.	.	a	.	a	.
	PSME/LIBO, SYAL	.	(s)	C	(s)	(S)	.	.	.	.	.	.	.	.	.
	PSME/LIBO, CARU	.	(s)	C	(S)	(S)	.	.	.	.	.	a	.	.	.
	PSME/LIBO, VAGL	.	(s)	C	S	(s)	a	a	.	.	.	a	.	.	.
	PSME/SYAL, CARU	.	(S)	C	(s)	a	a	.	.	.	.	.	.	.	.
	PSME/SYAL, SYAL	.	(S)	C	(s)	.	.	.	.	.	.	.	.	a	.
	PSME/CARU, ARUV	.	S	C	s	(s)	.	.	.	.	.	.	.	.	.
	PSME/CARU, CARU	.	a	C	(S)	(s)	.	.	.	.	.	a	.	a	.
	PSME/CAGE	.	(s)	C	a	.	.	.	.	.	.	a	.	(c)	.
4	PICEA/LIBO	.	a	S	S	.	C	.	.	.	.	a	.	a	.
	ABLA/VACA	.	.	(s)	S	a	(c)	.	.	.	.	c	.	a	.
	ABLA/CACA, CACA	.	.	a	S	.	s	.	.	.	.	C	.	a	.
	ABLA/LIBO, VASC	.	.	s	S	a	s	.	.	.	.	C	.	a	.
	ABLA/XETE, VASC	.	.	(s)	S	.	s	.	.	.	.	C	a	(s)	.
	ABLA/VAGL	.	.	S	S	.	S	.	.	.	.	C	.	(s)	.

(continued)

Fire Group	Habitat type/ phase	JUSC	PIPO	PSME	PICO	LACO	PICEA	ABGR	PIMO	THPL	TSHE	ABLA	TSME	PIAL	LALY
	PICEA/GATR	.	(s)	S	S	.	C	.	.	.	.	a	.	a	.
	ABLA/OPHO	.	.	s	.	s	S	.	s	.	a	C	.	.	.
	ABLA/CLUN, CLUN	.	(s)	S	(S)	S	S	(s)	(s)	a	a	C	.	a	.
	ABLA/CLUN, ARNU	.	a	s	(s)	S	S	(s)	(S)	.	a	C	.	.	.
	ABLA/CLUN, VACA	.	(s)	S	S	s	s	a	a	.	.	C	.	a	.
	ABLA/CLUN, XETE	.	.	S	S	S	S	a	(s)	.	a	C	(c)	a	.
	ABLA/CLUN, MEFE	.	.	S	s	s	S	(C)	(s)	a	a	C	(c)	a	.
	ABLA/GATR	.	a	S	S	(s)	S	.	.	.	.	C	.	.	.
	ABLA/CACA, CACA	.	.	.	S	.	S	.	.	.	.	C	.	(s)	.
	ABLA/CACA, GATR	.	.	.	s	.	S	.	/	.	.	C	.	.	.
	ABLA/LIBO, LIBO	.	(s)	S	S	(S)	S	a	.	.	.	C	.	a	.
5	ABLA/LIBO, XETE	.	a	S	S	S	s	a	(s)	.	.	C	.	.	.
	ABLA/MEFE	.	.	(S)	S	(s)	S	a	a	.	.	C	a	(s)	.
	TSME/MEFE	.	.	(s)	s	s	s	.	(s)	.	.	C	C	(s)	.
	ABLA/XETE, VAGL	.	(s)	S	S	(s)	s	a	(s)	.	.	C	a	(s)	.
	TSME/XETE	.	.	(s)	S	(s)	s	a	(s)	.	.	C	C	(s)	.
	ABLA/LUHI, VASC	.	.	.	(s)	.	S	.	.	.	.	C	a	S	.
	ABLA/LUHI, MEFE	.	.	.	a	.	S	.	.	.	.	C	.	s	(C)
	TSME/LUHI, VASC	.	.		(s)	.	s	.	.	.	.	C	C	s	.
	TSME/LUHI, MEFE	.	.	.	a	.	s	.	.	.	.	(C)	C	a	.
6	PIAL-ABLA h.t.'s	.	.	.	.	.	(C)	.	.	.	.	(C)	.	(C)	.
	LALY-ABLA h.t.'s	.	.	.	.	.	(c)	.	.	.	.	(C)	.	(C)	(C)
	PIAL h.t.'s	.	.	a	.	.	a	.	.	.	.	a	.	C	.
	ABGR/XETE	.	s	S	S	S	a	C	a	a	.	a	.	.	.
	ABGR/CLUN, CLUN	.	(s)	S	(s)	(s)	(s)	C	(s)	a	.	(c)	.	.	.
	ABGR/CLUN, XETE	.	a	S	s	S	(S)	C	s	a	a	c	.	.	.
	THPL/CLUN, CLUN	.	a	S	(s)	S	S	(c)	(s)	C	a	(c)	.	.	.
7	THPL/CLUN, ARNU	.	.	S	a	S	(S)	(c)	(s)	C	(c)	(s)	.	.	.
	THPL/CLUN, MEFE	.	.	S	S	S	S	a	(s)	C	.	c	.	.	.
	THPL/OPHO	.	.	s	.	a	s	(s)	a	(C)	(C)	(c)	.	.	.
	TSHE/CLUN, ARNU	.	a	(s)	a	S	(S)	(c)	.	c	C	(c)	.	.	.
8	SCREE	.	(C)	C	a	.	(c)	.	.	.	.	(c)	.	(c)	.

[1] C = major climax; S - major seral; a = accidental; c = minor climax; s = minor seral; ( ) = in certain areas of the type.

APPENDIX D

APPENDIX D

Index of Habitat Types and Phases
Occurring in the Lolo National Forest

ADP code[1]	Abbreviation	Fire Group	Page Number
100	*PINUS PONDEROSA* CLIMAX SERIES		
130	PIPO/AGSP	2	6
140	PIPO/FEID h.t.		
141	FEID phase	2	6
142	FESC phase	2	6
160	PIPO/PUTR h.t.		
161	AGSP phase	2	6
	FEID phase	2	6
170	PIPO/SYAL h.t.		
171	SYAL phase	2	6
200	*PSEUDOTSUGA MENZIESII* CLIMAX SERIES		
210	PSME/AGSP h.t.	4	13
220	PSME/FEID h.t.	5	19
230	PSME/FESC h.t.	4	13
250	PSME/VACA h.t.	6	20
260	PSME/PHMA h.t.		
261	PHMA phase	6	20
262	CARU phase	4	13
280	PSME/VAGL h.t.		
281	VAGL phase	6	20
282	ARUV phase	6	20
283	XETE phase	6	20
290	PSME/LIBO h.t.		
291	SYAL phase	6	20
292	CARU phase	6	20
293	VAGL phase	6	20
310	PSME/SYAL h.t.		
311	AGSP phase	4	13
312	CARU phase	6	20
313	SYAL phase	6	20
320	PSME/CARU h.t.		
321	AGSP phase	4	13
322	ARUV phase	6	20
323	CARU phase	6	20
324	PIPO phase	4	13
330	PSME/CAGE h.t.	5	19
340	PSME/SPBE h.t.	4	13
400	*PICEA* CLIMAX SERIES		
440	PICEA/GATR h.t.	9	38
470	PICEA/LIBO h.t.	7	30
500	*ABIES GRANDIS* CLIMAX SERIES		
510	ABGR/XETE h.t.	11	54
520	ABGR/CLUN h.t.	11	54
521	CLUN phase	11	54
523	XETE phase	11	54

(continued)

Abbreviation	Fire Group	Page Number
THUJA PLICATA CLIMAX SERIES		
THPL/CLUN h.t.		
CLUN phase	11	54
ARNU phase	11	54
MEFE phase	11	54
THPL/OPHO h.t.	11	54
TSUGA HETEROPHYLLA CLIMAX SERIES		
TSHE/CLUN h.t.		
ARNU phase	11	54
ABIES LASIOCARPA CLIMAX SERIES		
Lower subalpine h.t.'s		
ABLA/OPHO h.t.	9	38
ABLA/CLUN h.t.		
CLUN phase	9	38
ARNU phase	9	38
VACA phase	9	38
XETE phase	9	39
MEFE phase	9	39
ABLA/GATR h.t.	9	39
ABLA/VACA h.t.	7	30
ABLA/CACA h.t.		
CACA phase	9	39
GATR phase	9	39
VACA phase	7	30
ABLA/LIBO h.t.		
LIBO phase	9	39
XETE phase	9	39
VASC phase	7	30
ABLA/MEFE h.t.	9	39
TSME/MEFE h.t.	9	39
ABLA/XETE h.t.		
VAGL phase	8	38
VASC phase	7	30
TSME/XETE h.t.	8	38
ABLA/VAGL h.t.	7	30
Upper subalpine h.t.'s		
ABLA/LUHI		
VASC phase	10	48
MEFE phase	10	48
TSME/LUHI h.t.		
VASC phase	10	48
MEFE phase	10	48
Timberline h.t.'s		
PIAL-ABLA h.t.'s	10	49
LALY-ABLA h.t.'s	10	49
PIAL h.t.'s	10	49
Miscellaneous		
Scree	0	4
Forested rock	0	4
Meadow	0	5
Grassy bald	0	5
Alder glade	0	5

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[1] Automatic data processing code for National Forest use.

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Davis, Kathleen M., Bruce D. Clayton, and William C. Fischer. 1980. Fire ecology of Lolo National Forest habitat types. USDA For. Serv. Gen. Tech. Rep. INT-79, 77 p. Intermountain Forest and Range Experiment Station, Ogden, Utah 84401.

Provides information on fire as an ecological factor for Lolo National Forest habitat types. Identifies "Fire Groups" of habitat types based on fire's role in forest succession. Describes forest fuels and suggests considerations for fire management.

KEYWORDS: fire ecology, forest ecology, forest fire, fire management, habitat types, forest fuels.

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The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

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USDA Forest Service
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RESEARCH SUMMARY

This report describes Idaho's forest products industry in the year 1973. Data were gathered as the result of a study requested by industry, the USDA Forest Service, and the Idaho Legislature.

The study covered a high percentage of the firms that operated in Idaho during 1973.

The report describes sources of raw materials and discusses production of lumber, posts and poles, cedar products, and plywood/veneer. Appendix A presents detailed results; Appendix B describes survey methods.

Some of the study's major highlights are:

- Of the 209 forest product firms operating in Idaho during 1973, the study received cooperation from 122 sawmills, 25 posts/pole plants, 40 cedar products manufacturers, 5 plywood/veneer plants, and 2 chipping operations. Fifteen firms did not respond.
- Nearly 2 billion board feet of timber was used by Idaho's forest products industry during 1973.
- Idaho, Shoshone, Clearwater, Bonner, and Kootenai Counties produced almost 60 percent of the timber consumed.
- Sawmills consumed 79 percent of the timber processed in 1973.
- The industry is dominated by a small number of large firms under corporate ownership.
- The USDA Forest Service supplied 45 percent of the timber consumed in 1973.
- Douglas-fir, true firs, and ponderosa pine are the dominant commercial species.
- Most lumber, plywood, veneer, and cedar products produced in Idaho were shipped to consumers in the eastern United States.

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INTRODUCTION

Although forestry is one of Idaho's leading businesses, little information has en published about the industry. This report describes the forest products industry r the year 1973 based on a census of forest products firms operating in Idaho. For is census a firm was defined as a single operating plant at one location. Thus, one mpany could own and operate more than one firm. Furthermore, only primary forest oducts firms were surveyed in the census. These firms included sawmills, post and le plants, cedar products mills, plywood and veneer mills, and chippers. Most loggers xcept those directly employed by the firms surveyed) and all secondary manufacturers obile home, door, molding, and paper manufacturers, etc.) were excluded. Although percent of the firms queried did not respond, the data adequately represent the dustry. A detailed description of the study methods can be found in Appendix B.

The report includes sections describing manufacturing firms, raw material supply d processing, production, and marketing. Although this information is applicable to 73, it nevertheless provides a useful description and a benchmark from which changes n be judged.

MANUFACTURING FIRMS AND PRODUCTS

Small Sawmills Are the Most Numerous Firms

Of the forest products firms in Idaho, 63 percent were classified as sawmills, 12 rcent as post and pole plants, 20 percent as cedar product mills. In addition, five ywood/veneer (3 percent) and three chipping (1 percent) plants existed. Although wmilling account for the most firms in the forest products industry, the number has clined during the past decade. The plywood/veneer sector, by comparison, has increased number of firms (Setzer and Wilson 1970; Schuster and others 1974). While some rms produced more than one product (lumber and veneer), most firms specialized in one oduct.

As shown in table 1, most of the firms surveyed in 1973 were small operations in rms of annual wood consumption. Fifty-eight percent of the sawmills and almost all e post, pole, and cedar plants consumed less than 10 million board feet annually. The ywood/veneer firms were generally larger, and they consumed an average of 50 million ard feet annually.

Table 1.--Idaho's forest products industry by size of firm (MM bd. ft. wood consumed) and product, 1973

Size class	Product		
	Lumber	Cedar	Post/poles
MM bd. ft.	*- - - - - - - Number of firms - - - - - -*		
Less than 10	67	40	25
10-19	14	--	--
20-29	8	--	--
30-39	10	--	--
40-49	7	--	
50+	[illegible]	--	
Unknown	10	--	--
Total	122	40	25

[1] Number includes as least one firm from a larger size class added to avoid disclosure of that firm's consumption.

Most Firms Are Located in North Idaho

Most forest products firms are located in Idaho County and the nine counties north of it (fig. 1). Manufacturing plants are also concentrated in southeast Idaho and the Boise Valley. The major reason for areas of concentration is a large supply of nearby timber.

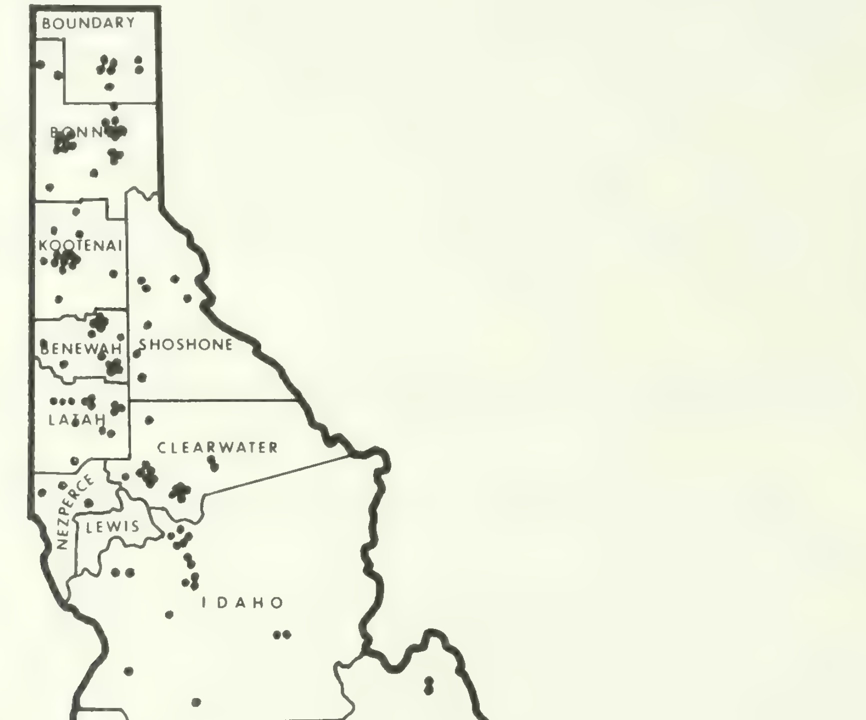

Figure 1.--Location of forest product industry firms in Idaho, 1973.

Most Processing Firms Are Owned by Corporations

Of the 194 firms interviewed, 44 percent were corporations, 17 percent partner-hips, and 39 percent single-owner proprietorships. Twenty-nine (15 percent) of the lants included in the survey were owned by six large corporations. Other corporations lso owned more than one plant but no partnership or single individual owned more than ne plant. Some corporations are multi-state firms with headquarters located in other tates.

Nearly 96 percent of the total volume of timber used during 1973 was processed by rporate-owned plants. Many of these corporations were owned by local people, but most f the 1973 volume was used by the six major firms that operated in Idaho.

Most Firms Are Relatively Stable

Firms seldom change ownership or location, as shown in table 2. Most firms have emained at a single location under the present ownership an average of 14 years. tability of location is particularly notable when comparing corporations (18 years) to ingle owners (12 years). Ownership stability, however, does not necessarily mean perating stability, as table 3 shows. Sixty percent of the firms reported operating ear round; 20 percent operated 6 months or less.

able 2.--*Firms in Idaho's forest products industry by years in locations and length of ownership, 1973*

	Years of ownership					
ears in location	0-2	3-5	6-9	10-20	21+	Total
	- - - - - - - - - Number of firms - - - - - - - - - -					
0-2	17	5	0	1	1	24
3-5	1	16	0	1	1	19
6-9	6	2	17	2	--	27
10-20	4	6	2	33	1	46
21+	1	3	5	7	35	51
Total	29	32	24	44	38	167

able 3.--*Firms in Idaho's forest products industry by months of annual operation and size of firm, 1973*

	Average annual operation, months						
ize of firm	6	7	8	9	10	11	12
MM bd. ft.	- - - - - - - - - -Number of firms- - - - - - - -						
0-4	35	4	3	2	12	7	48
5-9	--	1	--	1	3	1	14
10-19	--	--	--	1	1	1	13
20+	--	--	--	--	1	--	30
Total	35	5	3	4	17	9	105

Forest Industry Employment is Concentrated in North Idaho and in Sawmilling

The information in figure 2 indicates that 75 percent of the 1973 Idaho forest industry employment of 8,118 employees is located in 10 northern counties. Other major centers of employment include Boise, Gem, Fremont, and Lemhi Counties. Employment is typically centered in particular towns: Sandpoint (Bonner County), Lewiston (Nez Perce), Grangeville (Idaho), Bonners Ferry (Boundary), and Emmett (Gem). The communities of Weippe, Potlatch, Kooskia, Moyie Spring, Priest River, St. Maries, and Horseshoe Bend have been historically "timber towns" because timber is the main industry. Of the 8,118 employees reported, 90 percent worked for corporations, and only 6 percent worked for single-owner firms.

The employment figures presented do not include all forestry-related employment.[1] For example, the 739 employees listed as working in logging probably represented less than one-third of the total number in logging, because that sector was not specifically surveyed. Also excluded are the employees of the secondary wood products manufacturers and paper mills, also not surveyed.

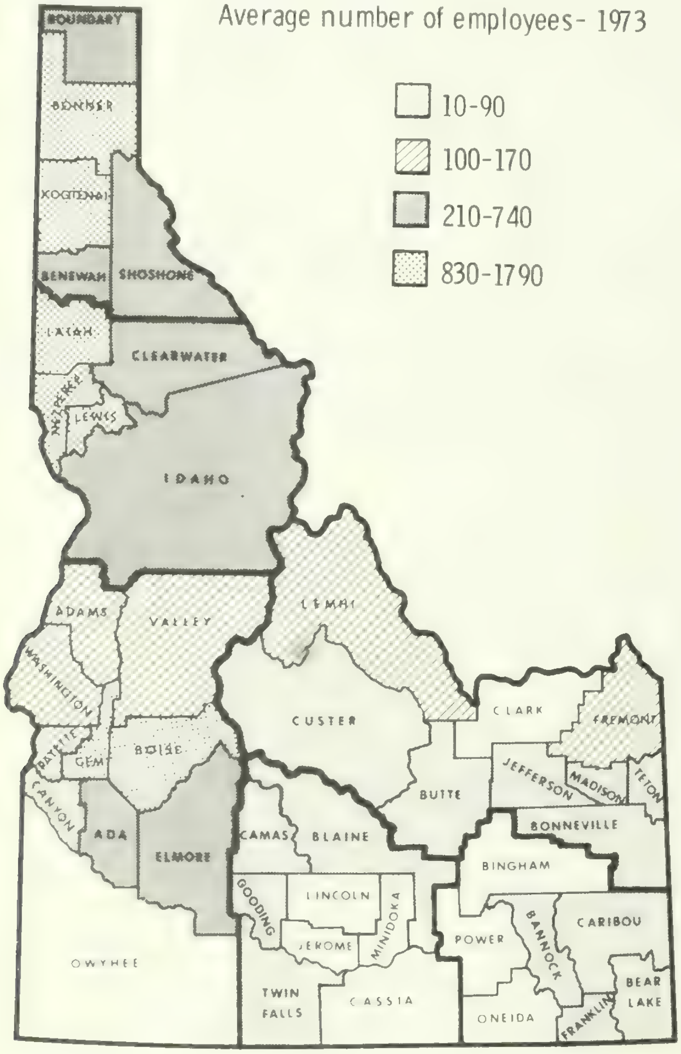

Figure 2.--Idaho forest products industry employment by county.

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[1] Schuster and others (1974) and Schuster and others (1975) provide additional estimates of forest industry employment as well as comparisons with other Idaho industry employment.

WOOD SUPPLY

Sawmills Consumed 79 Percent of the Timber in 1973

Idaho's forest products industry used 1.9 billion board feet of timber during 1973.
ien compared to the 1970 forest inventory on commercial timberland in Idaho (USDA
)73), this volume was less than one-hundredth of 1 percent of the net volume of saw-
mber but was nearly 97 percent of the net annual growth.

As shown in table 4, sawmills consumed the largest proportion of timber. Plywood/
neer/chip mills consumed 15 percent--and the most timber per firm--while the post/pole
d cedar products claimed the other 6 percent.

ıble 4.--*Volume of timber, number of firms, and average volume per firm in Idaho's forest products industry, 1973*

pe of firm	Number of firms	Volume	Average volume per firm
		- - - - - - - - - - *M bd. ft.*	- - - - - - - - - -
ıwmills	122	1,538,738	12,613
edar products	40	51,364	1,284
ost/pole	25	66,763	2,671
ywood/veneer and chipping plants	7	287,638	41,091
Total	194	1,944,503	10,023

A Few Large Firms Used Most of the 2 Million Board Feet Consumed

The data in figure 3 indicate that the 13 largest firms used 45 percent of the
mber while the 30 smallest firms used less than 1 percent of the total volume.
is heavy concentration of use by large mills will probably continue to put economic
essure on small operators in competition for timber.

True Firs and Douglas-firs Are the Major Commercial Species

The forest industry firms interviewed provided relatively complete estimates of
mber used and identification by species. Only 3 percent of the total volume used was
t identified. The data in figure 4 indicate that true firs and Douglas-fir are the
minant species of timber used, accounting for over one-third of the total volume. The
rs were followed in importance by ponderosa pine (14 percent), white pine (11 percent)
d cedar (9 percent).

The timber species utilized varies among counties (see table 18 page 26). For
ample, industries in southeast Idaho predominantly use Douglas-fir; firms in western
aho (Valley and Washington Counties) use mostly ponderosa pine; firms in north Idaho
e a mixture of species.

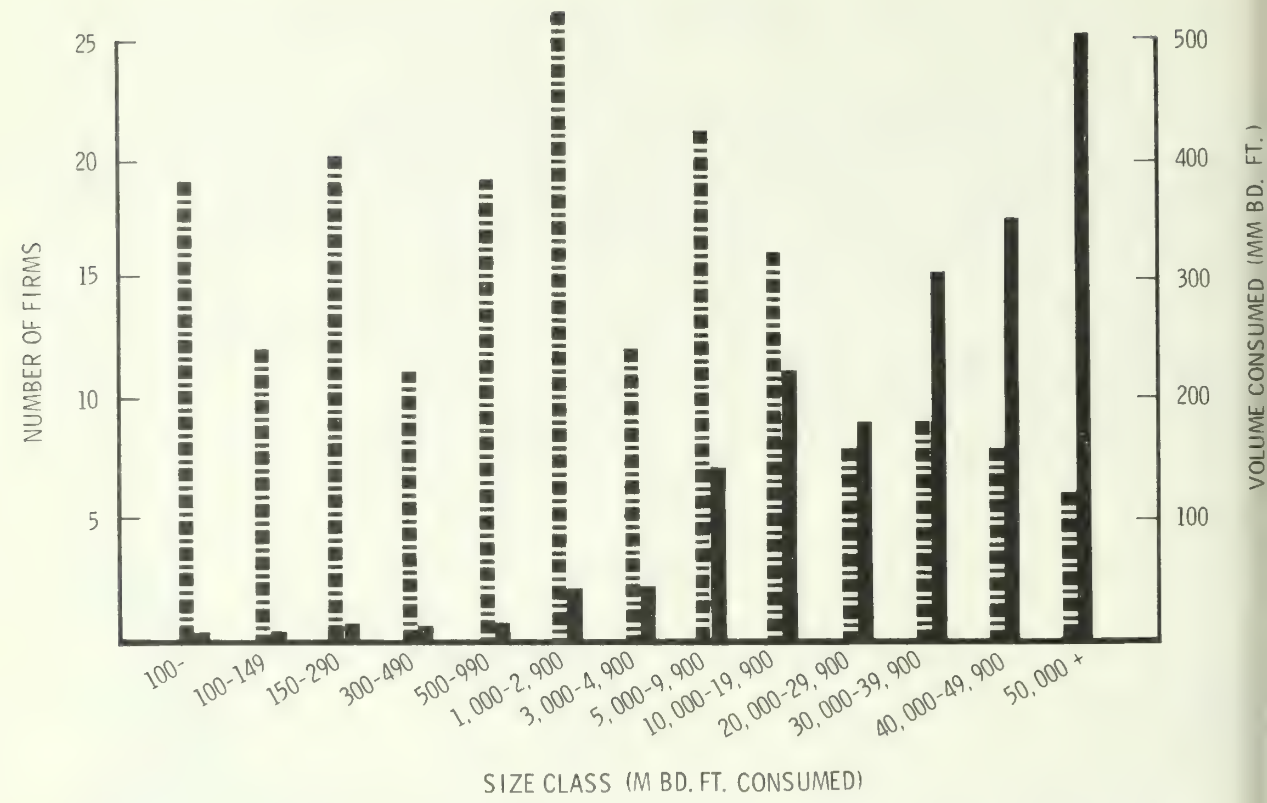


Figure 3.--Number of firms and volume of timber used in Idaho's forest products industry by size class, 1973.

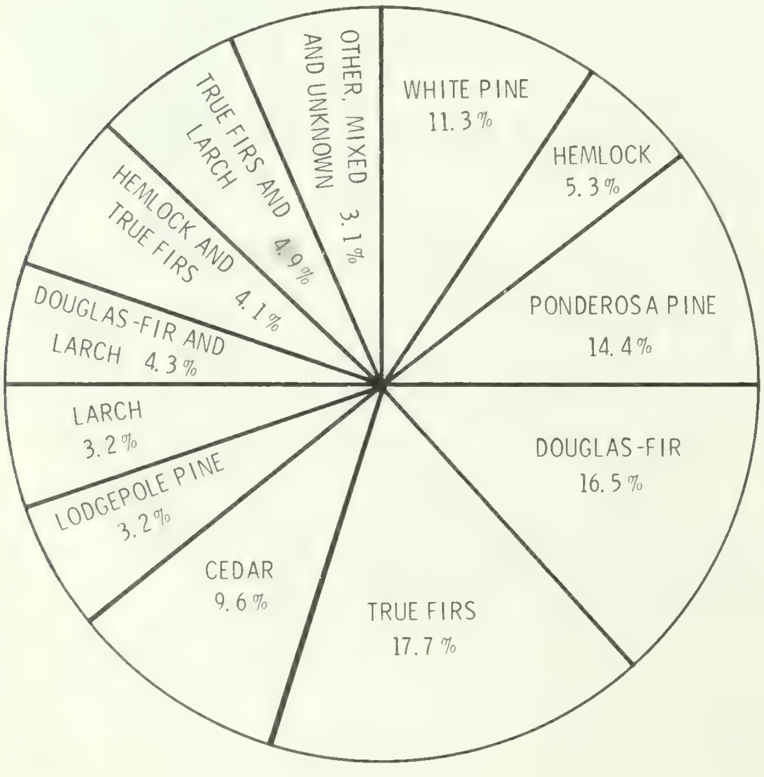
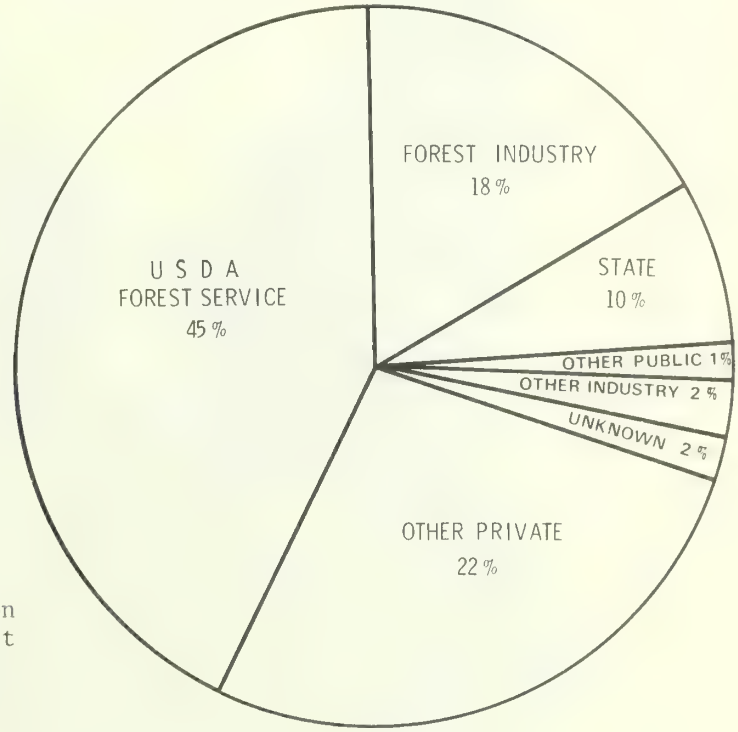


Figure 4.--Percentage distrib tion of timber used in Idah forest products industry by species, 1973.

Firms Consume About Equal Portions of Forest Service and Private Timber

Although the Forest Service administers almost 70 percent of Idaho's commercial orest land (Green and Setzer 1974), only 45 percent of the timber used by the forest roducts industry came from National Forests. As figure 5 illustrates, private lands roduce 42 percent of the timber consumed. This represents a slight increase in private upply from 1967 (38.3 percent) as reported by Koss (1975).

The changing pattern of timber source was also reflected in the data provided by he firms. Forest products firms indicated that although they obtained 56 percent of heir timber from Forest Service lands during the past 5 years, they expect to obtain nly 49 percent during the next 5 years. Decreased volume is expected to be "offset" by orresponding increases from "other private" lands. In contrast, research by Hatch and thers (1976) indicates that the largest increases will come from Forest Service lands.



igure 5.--Percentage distribution of timber used in Idaho's forest products industry by ownership, 1973.

Most Timber is Harvested and Processed in North Idaho

Data in figure 6 indicate that almost 60 percent of the timber used in Idaho riginated in five counties--Idaho (9.5 percent), Clearwater (23.5 percent), Shoshone 7.4 percent), Bonner (10.1 percent), and Kootenai (7.9 percent). Approximately 12 ercent of the timber used in Idaho was not identified in origin. Most of this volume as used in Valley, Shoshone, Gem, Ada, and Adams Counties, indicating that volumes arger than those reported were harvested in these and neighboring counties. The argest single destination was the Nez Perce-Latah-Lewis Counties processing complex hat used 17.9 percent of the State's volume. Other leading manufacturing counties fig. 7) include Benewah (9.9 percent), Bonner (10.4 percent), Clearwater (6.2 percent), daho (10.8 percent), and Kootenai (11.1 percent). These volumes generally follow the ame pattern of origin and destination as reported by Koss (1975), but many of the smaller volume" counties had large differences. These differences may stem from the act that the people Koss interviewed knew origin and estimated destination, while those e interviewed knew destination and estimated origin. Koss's study does not estimate mports to the State, while this study does not estimate exports to other States.

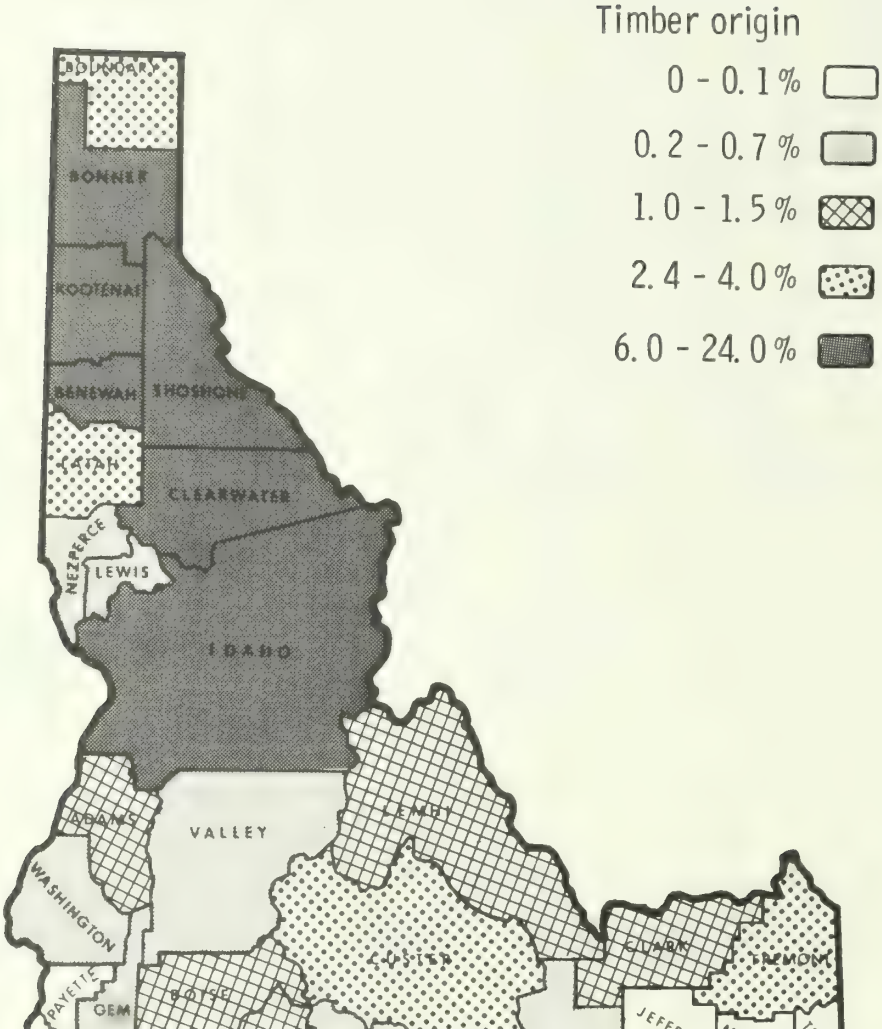


Figure 6.--Origin of timber for Idaho's forest products industry by county and percentage of Idaho timber consumed.

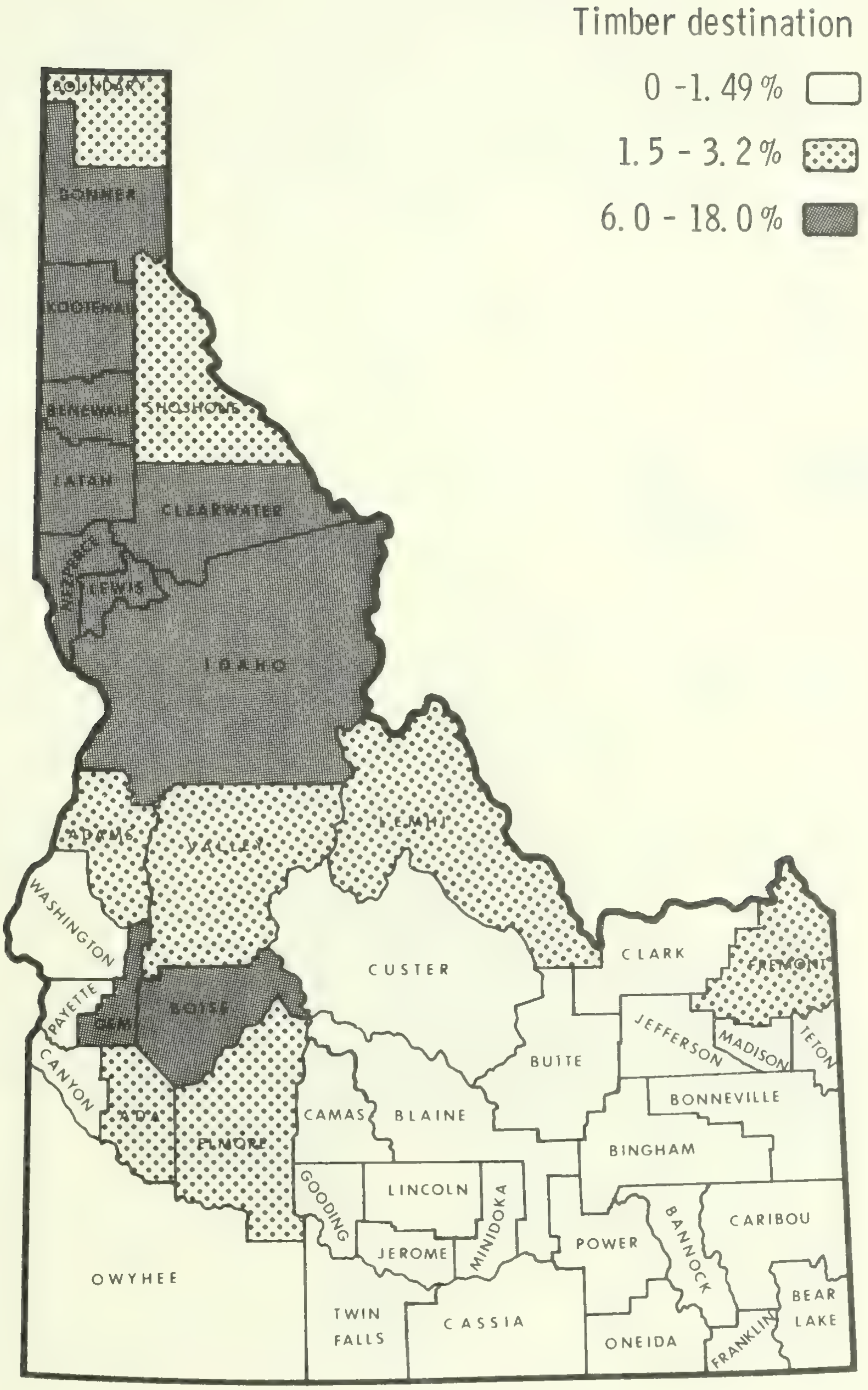


Figure 7.--Timber distribution for Idaho's forest products industry by county and percentage of total consumed.

Nearly 95 Percent of Timber Processed Comes from Idaho

Idaho firms not only buy timber from lands within the State, but also purchase timber from neighboring states (fig. 8). For example, nearly 4 percent of the total volume of timber used in Idaho originates in Washington and is manufactured by firms in the Priest River area of Bonner County. Montana also supplied timber for the Idaho forest products industry--26 million board feet--during 1973. The small volume of imported timber indicates that Idaho's forest industry is relatively insulated from the timber supply in other states. (These volumes do not include the more than 246 million board feet of unidentified origin.) However, a few local areas (Priest River) may be dependent on timber imported from neighboring states.

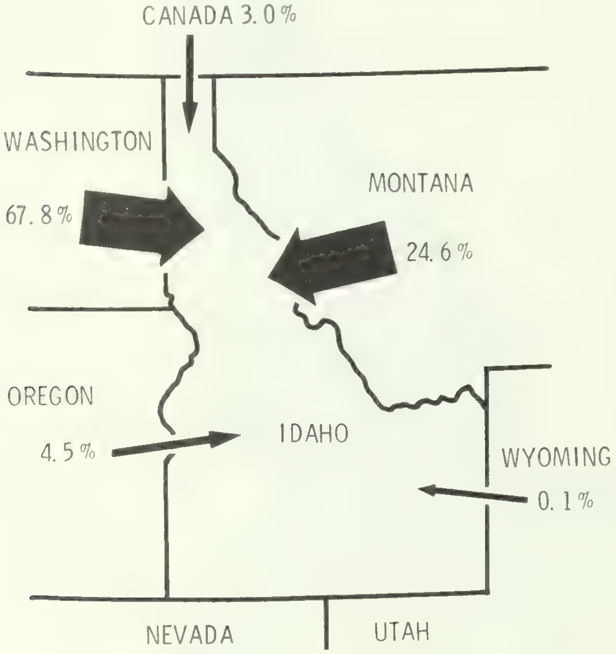


Figure 8.--Percent distribution of timber imports to Idaho's forest product industry by percent of total imports and import origin, 1973.

Log Haul Distances Average 38 Miles

Average and maximum haul distances between mill and source of logs were requested in the survey. Average haul distance was 38 miles, with a range from 0 to 220 miles. The few cases of hauls over 400 miles were shipments of poles. In general, mills in southcentral Idaho had the longest hauls, as shown in figure 9. Kootenai County mills in north Idaho also averaged over 40 miles hauling distance.

Competition and Forest Service Policies Cited as Major Supply Problems

Responses to the question, "What is your major obstacle in obtaining logs?" are categorized in table 22 (page 33). In about 28 percent of the responses, Forest Servic environmental and sales restrictions and sale size were the main problems. About 40 percent of the problems related to competition--ranging from high stumpage prices to lack of raw materials. Poor weather, lack of financing, and high logging costs were other factors. Sixteen percent of the firms either had no problems or did not respond.

Cedar products and pole/post manufacturers often charged that Government sale policies favored sawmills. They thought that sales should be designed so poles or ceda would be harvested before the sawlogs were sold. They charged that valuable cedar tree were being burned as slash.

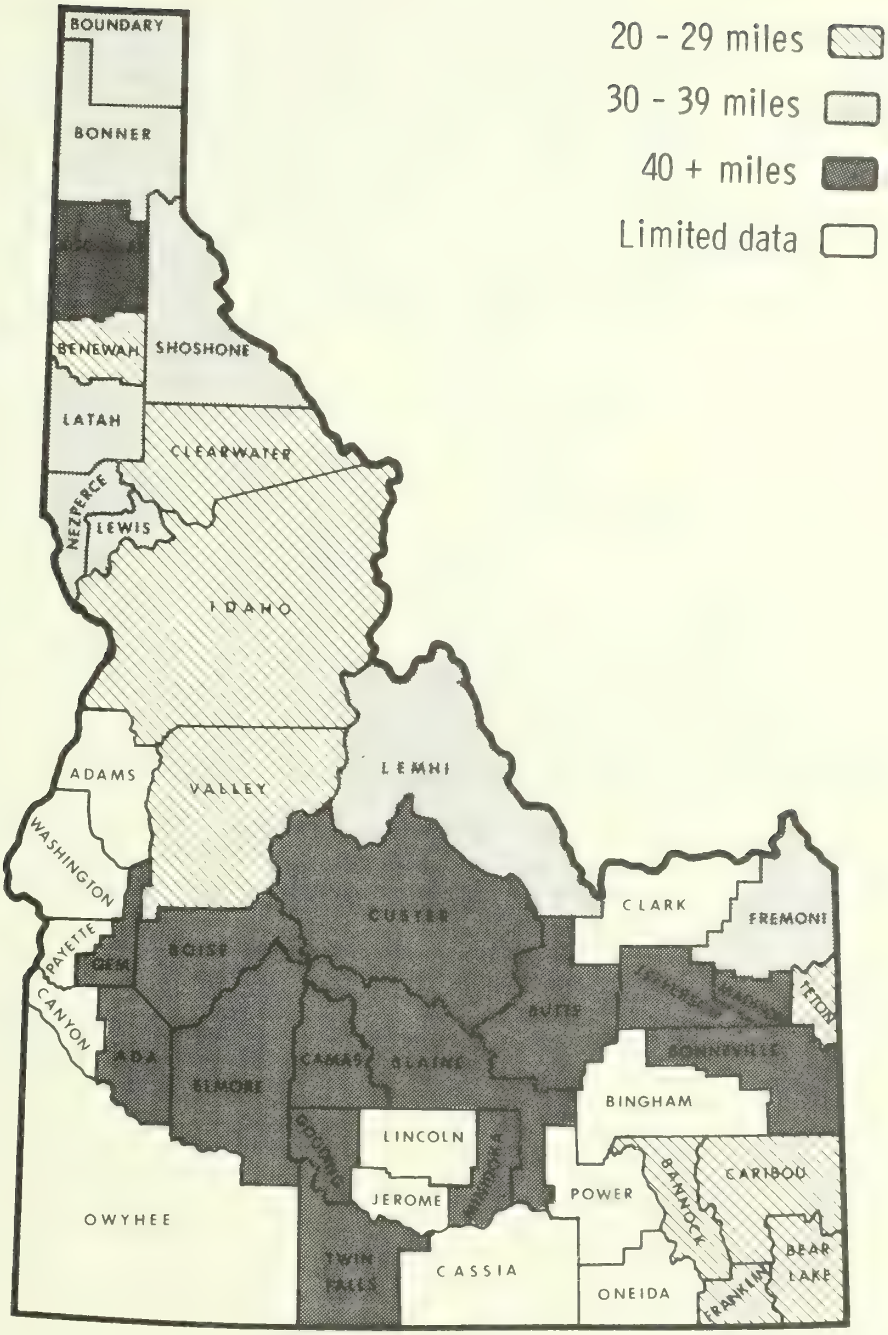


Figure 9.--Average log haul distance by county of destination and distance class, 1973.

FOREST INDUSTRY PRODUCTION

Lumber Industry

LUMBER PRODUCTION TOTALED APPROXIMATELY 2 BILLION BOARD FEET

Seventy-four sawmills reported producing 1.3 billion board feet of lumber from 1.0 billion board feet of logs, for an overrun of approximately 32 percent (table 5). If this average overrun is applied to the total volume used by sawmills, an estimated 2 billion board feet (1.32 x 1,538,733 M bd. ft. from table 4) of lumber was produced in Idaho during 1973. This is close to the 1.91 billion board feet production estimate by the Western Wood Products Association (1973) for Idaho. This volume represents approximately 5 percent of the lumber produced nationally. Historically, Idaho has maintained this share of the national market as the fourth leading lumber producing state--surpassed only by Oregon, Washington, and California (Western Wood Products Association 1975).

Table 5.--*Timber consumption, lumber production, and overrun (lumber ÷ timber) for 74 Idaho sawmills by region (table 16), 1973*[1]

Area	Timber used	Lumber produced	Number of firms reporting	Overrun
		- - - - - *M bd. ft.* - - - -		
Region I (North)	479,361	667,225	31	1.39
Region II (Northcentral)	235,774	302,897	9	1.28
Region III (Southwest)	218,924	261,850	13	1.19
Region V and V (Southwest)	13,433	16,378	11	1.22
Region VI (Southcentral)	66,851	96,057	10	1.43
Total	1,014,343	1,344,407	74	1.32

[1] See table 16 page 24 for counties within regions.

SAWMILL NUMBERS DECLINE WHILE MILL OUTPUT RISES

Table 6 reflects a steady decline in the number of sawmills operating in Idaho from 1959 through 1973, with an increase of 184 percent in the volume of timber used per firm. If growth in the average mill size is due to economies of scale, the number of firms may continue to decline.

Table 6.--*Number of sawmills and average volume used by Idaho sawmills, 1959, 1962, and 1973*[1]

Year	Number of mills	Average volume per mill
		- - - - *M bd. ft.* - - -
1959	311	5,174
1962	193	7,855
1973	122	14,708

[1] Source for 1959 and 1962 data: Wilson and Spencer 1967.

LUMBER IS PRIMARILY SOLD TO EASTERN MARKETS

Sawmills reported selling nearly two billion board feet of lumber during 1973 (table 23 page 34). Of this total (fig. 10), 30.8 percent was sold to the Midwest, 22.7 percent to the East Coast, and 13.1 percent to firms in Idaho. Thus, the Eastern United Sates and local communities are the two primary markets for Idaho's lumber. Denver, Colo., received most of the lumber reported as being shipped to "other western states."

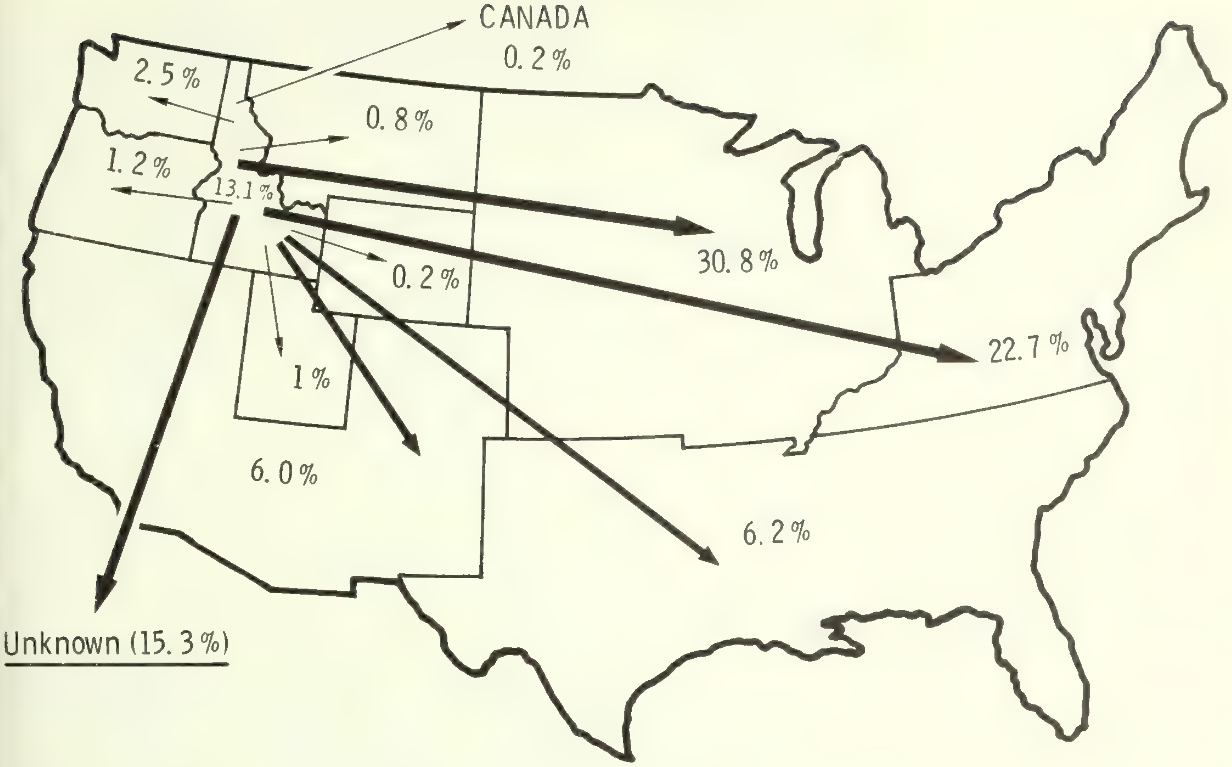


Figure 10.--Percentage distribution of Idaho lumber by destination, 1973.

SAWMILLING IS A BIG BUSINESS

The data in table 7 show expenditures for roundwood, wages, salaries, and operating expenses, and the total revenue received by sawmills. These data indicate manufacturing costs exceeded $143 per thousand board feet exclusive of returns to capital investments, such as land and buildings. For firms to break even on variable costs during 1973, the price of lumber would have to be $142.63 per M bd. ft. The average lumber price reported was $218.35 per M bd. ft. However, average returns minus the average costs do not indicate profits because: (1) different firms are commonly involved in various cost and return categories, (2) no allowance is made for changes in inventory, and (3) the cost of the fixed factors (primarily owner's salaries, management, and return to invested capital) is not included. Furthermore, these data are probably the least reliable of any obtained and do not include taxes.

Several inferences can be made from the expense and revenue data. First, 60 percent of the variable costs of operating a sawmill are spent for roundwood, and more than 25 percent for wages and salaries. This would indicate that timber pricing policies and bidding procedures can have a large impact on the profitability of a sawmill. Second, if the firms paid an average of $142.63 per M bd. ft to produce lumber, nearly 220 million dollars ($142.63/M bd. ft. x 1,538,733 M bd. ft. from table 4) would have been spent, and nearly 336 million dollars ($218.35/M bd. ft. x 1,538,733 M bd. ft.) worth of products would have been sold by the sawmilling industry in 1973.

Table 7.--*Average costs and revenues for Idaho sawmills, 1973*

Cost/return	Number of firms reporting	Average per firm	Average per M bd. ft.
		- - - - - - - - - Dollars	- - - - - - - - -
Wages and salaries	55	662,111	36.69
Roundwood	65	1,018,375	83.85
Rentals	8	73,028	2.90
Repair	35	70,465	5.09
Insurance	33	27,672	1.53
Marketing expense	12	78,591	5.82
Transportation	11	143,955	8.58
Contract labor	9	382,167	19.92
Operating expenses	54	82,094	5.66
Supplies	24	124,027	6.30
Other expenses	25	267,203	14.78
Total costs	38	2,275,389	142.63
Total revenue	60	2,657,206	218.35

EQUIPMENT VARIES WITH SAWMILL SIZE

The type, size, and amount of equipment used by Idaho sawmills varies considerably, as illustrated in table 8. These data indicate a strong relationship between equipment used and firm size. No small (less than 3 million bd ft) mill had a chipper or kiln, while most larger sawmills had at least one of each. The data in table 8 may also indicate the size a firm must attain before certain types of equipment can be added profitably. For example, a burner, chipper, band headsaw, and debarker appear to be justified only for mills using more than 5 million board feet of timber; use of kiln instead of air drying apparently requires a firm larger than 10 million board feet. Since larger mills use most of the timber and almost always have kilns, edgers, planers, and sanders, probably most of the lumber produced in Idaho is finished and ready for use.

Table 8.--*Number and type of equipment used by sawmills in Idaho, by size of firm (by M bd. ft. consumed), 1973*

	Size (M bd. ft. consumed annually)									
Equipment	Less than 500	500-1,000	1,000-3,000	3,000-5,000	5,000-10,000	10,000-20,000	20,000-30,000	30,000-40,000	More than 40,000	Total
Circle headsaw	24	7	2	3	8	4	0	1	0	49
Double circle headsaw	7	2	1	1	3	1	0	0	0	18
Band headsaw	0	2	2	1	9	9	7	12	17	59
Resaw	1	2	1	5	6	6	6	7	15	49
Chipper	--	--	--	2	10	8	7	5	10	42
Chipper headrig	--	--	--	--	--	1	3	5	2	11
Edger	20	10	8	6	16	15	7	9	20	111
Trimmer	4	5	7	5	15	10	5	8	15	74
Planer	14	3	8	2	15	14	5	8	20	90
Kiln	--	--	--	--	7	19	10	28	145	209
Burner	--	2	2	6	13	11	4	5	6	48
Peeler/debarker	1	1	--	2	11	13	7	7	13	55
Number of firms reporting	31	11	8	5	18	13	7	8	10	111

The Plywood and Veneer Industry

Plywood and veneer firms interviewed consumed 244,199 M bd. ft. of timber to pro-uce 546,817 thousand square feet of plywood and veneer during 1973. Most of this olume was shipped to the Midwest (36 percent), the South (17.5 percent), and East oast (17.6 percent), with 22.5 percent of unknown shipping destination.

Four of the five plywood/veneer plants that operated during 1973 provided some f the cost/return information requested. These four firms paid more than $10.3 illion in wages and salaries, an amount greater than the combined total wages and alaries paid by all post/pole and cedar product firms. Although plywood/veneer roduction occupies comparatively few plants, by other criteria (wages, volume of imber used, sales), it is second in importance to sawmilling in Idaho's forest roducts industry. If past trends continue, this segment of the industry may eventually urpass sawmilling in economic importance.

The Post and Pole Industry

The 25 post/pole firms interviewed reported using 66,763 M bd. ft. of timber uring 1973. Some firms are large and use large volumes of timber, but many firms re part-time operations using very small volumes of timber.

ONNER AND BOUNDARY COUNTIES ARE HE LEADING PRODUCER OF POLES/POSTS

Nearly 70 percent of the more than one million posts produced during 1973 were anufactured by firms in Boundary and Bonner Counties. Other counties that had post anufacturers included Ada, Elmore, Fremont, Lemhi, and Jefferson. Most of these irms are located near large stands of lodgepole pine, the primary species utilized. y comparison, more than 300,000 poles were manufactured during 1973, with leading roducers located in Bonner, Benewah, Ada, Elmore, Fremont, and Bonneville Counties.

IOST POSTS AND POLES SOLD IN WESTERN MARKETS

Approximately 90 percent of the poles and 85 percent of the posts produced in daho are sold in the Western States. Some areas produce special poles--hop poles ear Boise and potato cellar poles in southeast Idaho--but most of the poles are roduced for utility companies.

OLE/POST SALES TOTAL APPROXIMATELY $14 MILLION

Data in table 9 indicate that manufacturers had large gross revenues during 973. Approximately one-half of the total variable costs is spent for roundwood. lthough other expenses vary among individual firms, consistently large expenditures ere recorded for wages and salaries, contract labor, and supplies.

If the costs and returns in table 9 are assumed representative, then the industry pent $4.3 million for roundwood and sold $14.0 million in products during 1973. owever, generally the data are for above average size firms (3,351 M bd. ft. for able 9 firms versus 2,671 M bd. ft. for all firms) and thus may not be representative. ost of the total sales by post and pole operators were concentrated in a few large irms.

Table 9.--*Costs and revenue for Idaho post/pole operators, 1973*

Cost/return	Number of firms reporting	Average per firm	Average per M bd. ft.
		Dollars	Dollars
Wages and salaries	10	125,669	39.68
Roundwood	15	156,822	65.12
Rent	2	3,500	1.78
Repair	8	18,351	6.18
Insurance	7	9,853	2.81
Marketing	4	5,450	1.11
Transportation	4	23,700	4.97
Contract labor	4	77,207	17.73
Operating expenses	10	15,650	6.30
Supplies	7	36,763	12.03
Other	6	12,946	4.72
Total costs	12	491,468	130.28
Total revenue	14	727,360	210.49

POST/POLE EQUIPMENT VARIES AMONG MANUFACTURERS

The equipment used by post/pole operators is relatively simple for the major conversions occur during logging. The most common equipment include chainsaws and peelers (18 of the 26 operators used peelers or debarkers). Five operators owned headsaws, one used an edger, and two used trimmers. More than half of the operators had the capability to treat or preserve the poles and posts produced--with facilities varying from a soaking barrel to elaborate pressurized systems.

Cedar Products Industry

Cedar product firms used 51,364 M bd. ft. of timber during 1973. They were located in north Idaho, with the largest concentration of firms in Clearwater, Latah, and Benewah Counties. In general, this industry is characterized by small, independent private firms.

CEDAR PRODUCTS MARKETS NOT CLEARLY DEFINABLE

Many of the cedar processors interviewed did not estimate the volume or destination of products sold. Those firms reporting cedar products sales, however, shipped their products to the same primary areas as the lumber producers--the Midwest and Eastern United States.

CEDAR PRODUCT SALES TOTAL APPROXIMATELY $12 MILLION

Assuming the average cost and return data in table 10 are indicative of the industry, more than $12 million ($235.64 x 51,364 M bd. ft.) of material was sold, while payments were made of $3 million for wages and salaries, $4 million for roundwood, and $11.75 million for manufacturing costs. When measured by most criteria, this industry is not substantial, but it does provide employment for many independent operators.

Table 10.--*Costs and returns for Idaho cedar products firms, 1973*

ost/return	Number of firms reporting	Average per firm	Average per M bd. ft.
		Dollars	
ages and salaries	17	107,498	58.00
oundwood	16	115,231	74.22
entals	2	1,477	.98
epair	6	15,720	10.02
nsurance	3	5,632	1.98
arketing	2	32,710	10.72
ransportation	5	58,236	31.60
ontract labor	2	5,070	5.63
perating expenses	8	6,403	7.46
upplies	3	1,407	1.17
ther	2	401,550	131.65
Total cost	12	284,632	228.65
Total revenue	15	354,506	235.64

EDAR PROCESSORS HAVE LIMITED EQUIPMENT

As shown in table 11, one-third of the cedar processors had the capability of awing lumber (headsaws and edger); however, many operators did much of the manufacturng with hand tools such as axes and wedges.

Table 11.--*Number and type of equipment used by Idaho cedar processors, 1973*

Type of equipment	Number
ircle headsaws	13
and headsaws	3
ther saws	16
dgers	15
rimmers	3
urners	14
plitters	6
umber of firms reporting	35

Residues

Setzer and Wilson (1970) reported 92 million cubic feet (2.6 million cubic eters) of plant by-products produced by Idaho firms in 1966 and 38.9 million cubic eet (1.1 million cubic meters) in 1962. These volumes compare with the more than 03 million cubic feet (5.7 million cubic meters) reported sold during 1973 and the 96 million cubic feet (8.4 million cubic meters) reported produced. While some of his increase between surveys may be due to increased production of primary products, uch of the difference is probably due to the estimation procedure used. One reason or the difference in 1973 between production and sales is the use of residues for nergy production within the firm.

RESIDUES ARE MAINLY PROCESSED INTO PULP CHIPS

Data in table 12 indicate that nearly 60 percent of residues are processed into pulp chips. Most of the remaining residue is bark and sawdust. Residue volumes per thousand board feet are, with few exceptions, higher than those reported in other sources (Institute of Forest Products 1976; Bergvall and Gedney 1970; Manock and others n.d.). This suggests that some volumes in table 12 may be unrealistically high (bark, sawdust, shavings) and should be considered accordingly.

Table 12.--*Number of firms and amount of residue produced by Idaho's forest products industry, 1973*

Type of residue	Number of firms	Units of residue (200 ft^3= 5.66 m^3)	Units per M bd. ft. processed
Pulp chips	43	864,603	0.6587
Particle board chips	2	17,400	.3506
Coarse chips	1	4,558	.0836
Bark	8	300,013	.7274
Log trim	3	27,450	.1399
Sawdust	17	200,443	.2904
Shaving	11	64,268	.1355
Sander dust	1	663	.0442

IDAHO FIRMS USE MOST OF THE PROCESSED RESIDUES

Three chipping plants and 43 sawmills reported selling 1,016,542 units of residuals (chips, bark, shavings, sawdust) as pulp, bedding, particle board, and other products during 1973. Nearly 60 percent of the total volume sold was shipped to locations in Idaho. Other major sales went to western Washington (fig. 11).

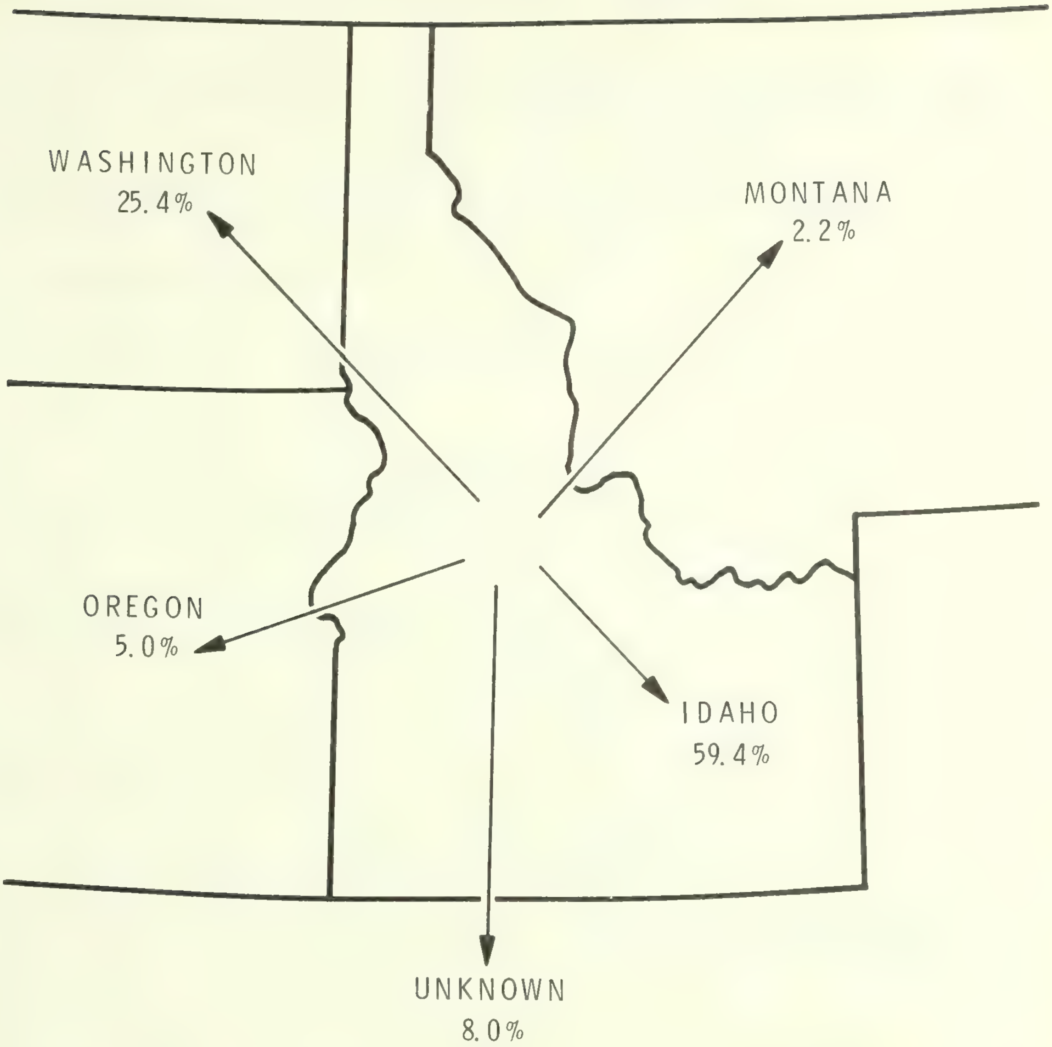


Figure 11.--Percentage distribution of residues produced by Idaho's forest products industry by origin and destination, 1973.

CONCLUSION

This paper represents the most detailed overview of Idaho's forest products industry published to date. Although it may be viewed as only 1 year in a constantly changing industry, this report can serve as a base from which changes can be measured in future studies.

Idaho's forest industry has been the leader among the Rocky Mountain States for some time, and it will probably continue to be one of America's leading forest product producing areas. In the future, competition from other areas--the South and West Coast--may well force Idaho's industry to modernize and become more productive.

Although the report has outlined some of the forest products industry's problems and strengths, much remains unknown. The work reported here may be useful as a basis for further research in determining the importance of forestry in Idaho and may also help resolve many of the difficult questions faced by firms within the industry.

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APPENDIX A

SELECTED TABULAR DATA
FOR IDAHO'S FOREST PRODUCTS

Table 16.--*Employment and number of firms by type, region, and county, 1973*

Region/County	Average number of employees	Number of firms		
		Lumber product	pole/post	cedar
Region I	3,063	50	6	14
Benewah	531			
Bonner	834			
Boundary	341			
Kootenai	1,113			
Shoshone	244			
Region II	3,031	21	2	26
Clearwater	517			
Idaho	733			
Latah/Nez Perce/Lewis	1,781			
Region III	1,534	21	5	--
Ada/Elmore	214			
Adams	116			
Boise/Gem	885			
Canyon/Washington	162			
Valley	157			
Owyhee/Payette	0			
Region IV	47	3	2	--
Blaine/Camas/Gooding/Twin Falls	47			
Cassia/Jerome/Lincoln/Minidoka	0			
Region V	27	11	--	--
Bannock/Caribou/Franklin	15			
Bear Lake	12			
Bingham/Oneida/Power	0			
Region VI	416	23	10	--
Bonneville/Jefferson/Madison	88			
Butte/Custer	37			
Fremont	130			
Lemhi	141			
Teton	20			
Clark	0			
Total	8,118	129	25	40

Table 17.--*Volume of logs used by Idaho's forest products industry by region and county, 1973 (M bd. ft., Scribner scale)*

Location	Sound live logs	Sound dead logs	Cull pulp	Total
Region I	641,057	15,692	62,657	719,406
Benewah	143,363	2,606	49,908	191,877
Bonner	191,347	3,150	8,249	202,746
Boundary	51,230	202	4,100	55,532
Kootenai	209,403	5,514	--	214,917
Shoshone	45,714	4,220	4,400	54,334
Region II	603,360	7,013	68,427	678,800
Clearwater	109,650	159	10,637	120,446
Idaho	191,256	5,165	13,438	209,859
Latah/ Nez Perce/Lewis	302,454	1,689	49,352	348,495
Region III	312,882	1,098	--	313,980
Ada/Elmore	46,989	--	--	46,989
Adams	43,987	5	--	43,992
Boise/Gem	141,926	--	--	141,926
Canyon/Washington	19,267	267	--	19,534
Valley	60,713	826	--	61,539
Region IV	9,493	12	--	9,505
Blaine/Camas/Gooding/ Minidoka/Twin Falls	9,493	12	--	9,505
Region V	5,802	1	--	5,803
Bannock/Caribou/Franklin	1,302	--	--	1,302
Bear Lake	4,500	1	--	4,501
Region VI	97,848	11,092	--	108,940
Bonneville/Jefferson/ Madison	27,855	819	--	28,674
Butte/Custer	10,011	965	--	10,976
Fremont	31,332	7,115	--	38,447
Lemhi	28,510	1,517	--	30,027
Teton	140	676	--	816
Unallocated volume	--	--	--	108,069
Totals	1,670,442	34,908	131,084	1,944,503

Table 18.--*Volume (M bd. ft.) by species* [illegible]

County	Douglas fir	Hemlock	True firs	White pine	Spruce	Ponderosa pine	Cedar	Lodgepole pine	Larch	[illegible]
Boundary	5,082	1,281	3,114	2,878	6,588	2,732	7,366	6,819	18,891	
Bonner	28,764	15,918	16,819	10,287	3,790	15,221	34,558	5,817	19,8[illegible]	[illegible]
Benewah	255	17,647	55,576	30,997	4,522	9,115	37,928	3,255		[illegible]
Kootenai	8,729	1,150	51,013	50,787	2,116	23,068	22,387	387	6,38[illegible]	[illegible]
Shoshone	3,176	1,000	1,896	15,092		2,203	6,363		2,111	
Region I	46,006	37,326	134,418	140,041	17,116	52,339	108,602	16,278	47,197	[illegible]
Clearwater	15,050		33,315	23,801	681	5,115	26,840	165	224	
Idaho	28,473		52,984	12,131	10,068	64,736	6,338	16,010	8,059	
Latah/Lewis/ Nez Perce	5,957	60,390	89,005	20,883	2,487	18,478	43,176	168		
Region II	49,480	60,390	175,304	56,815	13,236	88,329	76,354	16,343	8,283	
Ada/Elmore	11,106		5,000			29,096		1,756	51	
Adams	15,903		5,679		12,106	11		671	622	
Boise/Gem	52,444		11,870	1,881	957	67,740		3,775	3,238	
Canyon/ Washington	6,540		2,180		920	8,100		534	1,260	
Valley	17,213		8,238		10,383	22,251		1,852	1,602	
Region III	103,206		32,967	1,881	24,366	127,198		8,588	6,773	
Region IV	7,534				419			1,552		
Bannock/Franklin/ Caribou	1,098				2			71		33
Bear Lake	1,990		585		200			1,366		
Region V	3,088		683		202			1,437		33
Bonneville/Jefferson/Madison	23,359			215	114			1,986		
Butte/Custer	10,141				215	250		330		41
Fremont	30,799				3,990			7,648		
Lemhi	23,301				3,990			2,736		
Teton	213		16					587		
Region VI	87,813		16	215	4,319	250		16,287		40
MultiCounty	25,304	5,544		21,216	197	12,639	1,997	129		
Total	322,431	103,260	343,388	220,168	59,855	280,775	186,953	61,512	62,253	152

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Table 18.--*Volume (M bd. ft.) by species consumed by Idaho forest products by county, 1973*

County	Douglas-fir lodgepole pine	Douglas-fir larch	Hemlock True firs	True firs white pine	True firs larch	Spruce lodgepole pine	Ponderosa lodgepole pine	Hemlock white pine	Mixed	Unknown	Total
Boundary					281	320				180	55,532
Bonner		15,025	3,180				600	600	900	1,383	202,796
Benewah		17,725			13,385					974	191,877
Kootenai		27,413	4,979	1,500	11,342					1	214,918
Shoshone		7,003				1,376		11,112			54,334
Region I		67,191	8,159	1,500	25,008	1,696	600	11,712	900	2,538	719,407
Clearwater		165			11,123					3,671	120,446
Idaho		3,900			7,136						209,859
Latah/Lewis/ Nez Perce		12,593	9,663		49,755					35,940	348,495
Region II		16,658	9,663		68,314					39,611	678,800
Ada/Elmore											46,989
Adams					2,000		7,000				43,992
Boise/Gem											141,925
Canyon/ Washington											19,534
Valley											61,539
Region III					2,000		7,000				313,979
Region IV											9,305
Bannock/Franklin/ Caribou											1,302
Bear Lake	360										4,501
Region V	360										5,803
Bonneville/Jefferson/Madison											28,674
Butte/Custer											10,976
Fremont											38,147
Lemhi											30,027
Teton											816
Region VI											108,940
MultiCounty			22,328							18,715	108,069
Total	360	83,852	40,150	1,500	95,322	1,696	7,600	11,712	900	60,864	1,944,503

Table 19.--*Volume (M bd ft) of timber by ownership used by Idaho's forest product industry, 1973*

Location	State	Bureau of Land Management	Forest Service	Other public	Owned	Other industry	Other private	Unknown	Total
Benewah	32,305	481	42,925		40,815	18,532	54,545	2,274	191,877
Bonner	20,483		51,104	1,634	19,539	2,624	91,819	15,543	202,746
Kootenai	23,240	2,666	68,200	2,404	57,879		53,750	6,778	214,917
Boundary	3,404		27,529	2,400	8,031	1,200	12,968		55,532
Shoshone	3,494		27,354		6,154	2,016	15,080	236	54,334
Region I	82,926	3,147	217,112	6,438	132,418	24,372	228,162	24,831	719,406
Clearwater	26,678	73	25,094	111	34,697	7,627	18,166	8,000	120,446
Idaho	17,669	1,630	133,922	903	18,892		36,738	105	209,859
Latah/Nez Perce/Lewis	41,274	2,270	98,018		150,767	6,732	49,415	19	348,495
Region II	85,621	3,973	257,034	1,014	204,356	14,359	104,319	8,124	678,800
Ada/Elmore	3,264		41,475		720	27	1,503		46,989
Boise/Gem	7,848	1,960	93,137		7,526		29,807	1,648	141,926
Adams	1,827		33,349		2,842		5,974		43,992
Valley	3,370	84	34,030		8,271		15,302	482	61,539
Canyon/Washington			18,834				700		19,534
Region III	16,309	2,044	220,825		19,359	27	53,286	2,130	313,980
Cassia/Blaine/Gooding/ Minidoka/Twin Falls	415	159	8,921				10		9,505
Region IV	415	159	8,921				10		9,505
Bannock/Franklin/Caribou	510		334	225	33		200		1,302
Bear Lake			3,376		100		1,025		4,501
Region V	510		3,710	225	133		1,225		5,803
Bonneville/Jefferson/Madison			27,143		483		1,048		28,674
Butte/Custer			10,976						10,976
Fremont	300		38,007				140		38,447
Lemhi	850	850	28,327						30,027
Teton			674		120		22		816
Region VI	1,150	850	105,127		603		1,210		108,940
MultiCounty	14,500		56,970	720	1,870	570	23,340	5,099	108,069
TOTAL	201,431	10,173	869,699	8,397	358,739	39,328	416,552	40,184	1,944,503

Table 20.--Origin and destination of timber used (M bd. ft.) by the Idaho forest products industry by county, 1975

Destination	Origin Ada	Adams	Bannock	Bear Lake	Benewah	Bingham	Blaine	Boise	Bonner	Bonneville	Boundary	Butte	Camas	Caribou
Boundary									1,082		39,802			
Bonner					1,881				114,965		4,370			
Benewah					89,640									
Kootenai					14,796				7,038		3,099			
Shoshone					1,062									
Region I					107,379				123,085		47,271			
Clearwater														
Idaho														
Latah/Lewis/Nez Perce					14,114									
Region II					14,114									
Ada/Elmore							11,000							
Adams		16,222												
Boise/Gem	9,359							21,117						
Canyon/Washington		7,400												
Valley														
Region III	9,359	23,622					11,000	21,117						
Region IV							1,514						795	
Bannock/Franklin/Caribou			557			4				64				300
Bear Lake				4,461										40
Region V			557	4,461		4				64				340
Bonneville/Jefferson/Madison										47		50		
Butte/Custer												5,063		
Fremont														
Lemhi														
Teton														
Region VI										47		5,113		
Unknown									73,775		30,260			
Total	9,359	23,622	557	4,461	121,493	4	12,514	21,117	196,860	111	77,531	5,113	795	340

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Table 20.--Origin and destination of timber used (M bd. ft.) by the Idaho forest products industry by county, 19[illegible]

Destination	Cassia	Clark	Clear-water	Custer	Elmore	Franklin	Fremont	Gem	Idaho	Jefferson
	Origin									
Boundary										
Bonner			5,910						2,285	
Benewah			28,105							
Kootenai			17,502							
Shoshone			8,195							
Region I			59,712						2,285	
Clearwater			111,846						600	
Idaho			27,057						173,479	
Latah/Lewis/Nez Perce			258,816						4,105	
Region II			397,719						178,184	
Ada/Elmore					15,000		78			
Adams									4,150	
Boise/Gem								4,679		
Canyon/Washington									267	
Valley									400	
Region III					15,000		78	4,679	4,817	
Region IV	90			195	6,556		315			
Bannock/Franklin/Caribou						225	33			
Bear Lake										
Region V						225	33			
Bonneville/Jefferson/Madison		17,774					9,470			100
Butte/Custer	650	1,668		3,595						
Fremont		962					37,485			
Lemhi				3,400						
Teton							100			
Region VI	650	20,404		6,995			47,055			100
Unknown										
Total	740	20,404	457,431	7,190	21,556	225	47,481	4,679	185,286	100

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Table 20.--Origin and destination of timber used (M bd. ft.) by the Idaho forest products industry by county, 1973

Destination	Origin Kootenai	Latah	Lemhi	Lewis	Nez Perce	Power	Shoshone	Teton
Boundary								
Bonner	7,905	537					1,726	
Benewah	16,407	6,114					45,211	
Kootenai	94,181						76,802	
Shoshone	1,000	360					10,736	
Region I	119,493	7,011					134,475	
Clearwater								
Idaho				7,645	1,678			
Latah/Lewis/Nez Perce		54,980			3,918		4,286	
Region II		54,980		7,645	5,596		4,286	
Ada/Elmore	106							
Adams								
Boise/Gem								
Canyon/Washington								
Valley								
Region III	106							
Region IV								
Bannock/Franklin/Caribou						119		
Bear Lake						119		
Region V						119		
Bonneville/Jefferson/Madison								48
Butte/Custer								
Fremont			26,627					
Lemhi								
Teton								636
Region VI			26,627					684
Unknown	33,502						5,403	
Total	153,101	61,991	26,627	7,645	5,596	119	144,164	684

(con.)

Table 20. Origin and destination of timber used (M bd. ft.) by the Idaho forest products industry by county, [illegible]

	Origin								
Destination	Twin Falls	Valley	Ore.	Mont.	Wash.	Wyo.	Canada	Unknown	Total
Boundary				11,700			2,948		55,532
Bonner			3,070	4,530	53,822		220	1,525	202,746
Benewah					4,400			2,000	191,877
Kootenai					1,500				214,918
Shoshone								32,981	54,334
Region I			3,070	16,230	59,722		3,168	36,506	719,407
Clearwater								8,000	120,446
Idaho									209,859
Latah/Lewis/ Nez Perce					6,476			1,800	348,495
Region II					6,476			9,800	678,800
Ada/Elmore		233	1,377	27				19,168	46,989
Adams								23,620	43,992
Boise/Gem		11,699						95,071	141,925
Canyon/Washington			267		10,900			700	19,534
Valley		715						60,424	61,539
Region III		12,647	1,644	27	10,900			198,983	313,979
Region IV	195	45							9,505
Bannock/Franklin/ Caribou									1,302
Bear Lake									4,501
Region V									5,803
Bonneville/Jefferson/Madison								1,185	28,674
Butte/Custer									10,976
Fremont									38,447
Lemhi									30,027
Teton						80			816
Region VI						80		1,185	108,940
Unknown				9,726	5,403				108,069
Total	195	12,692	4,714	25,983	82,501	80	3,168	246,474	1,944,503

able 21.--*Distance (miles) from plant to location of purchased logs for Idaho's forest products industry by county, 1973*

lant Location	Maximum				Usual			
	Range	Mode	Median	Average	Range	Mode	Median	Average
enewah	7-200	70	52	60.7	2-60	30,50	20	24.3
onner	40-100	75	75	78.3	20-60	40	40	37.9
oundary	30-150	30	75	73.4	10-46	--	30	30.2
ootenai	45-150	130	127	112	20-100	35	35	43.1
hoshone	50-85	--	65	66.3	25-45	--	37	36.2
learwater	1-150	80	50	57.3	0-75	15	20	25.5
daho	15-100	15	45	48.8	2-60	5	15	21.9
atah/Lewis/Nez Perce	1-120	60	60	45.0	0-80	20,30	30	29.7
da/Elmore	80-450	--	138	200.3	60-220	60	77	111.6
dams	--	--	--	--	--	--	--	--
oise/Gem	30-150	150	150	110.0	15-60	60	60	45.0
anyon/Washington	--	--	--	--	--	--	--	--
alley	10-90	--	45	47.5	3-45	--	25	24.5
laine/Camas/Gooding/ Minidoka/Twin Falls	50-252	--	88	119.3	25-125	--	40	54.0
annock/Caribou/ Franklin	14-70	--	35	38.5	14-150	20	20	22.8
ear Lake	20-70	40	40	44.0	15-25	20	20	21.0
onneville/Jefferson/ Madison	75-85	80	80	80.0	30-75	--	50	53.6
utte/Custer	55-250	--	115	133.8	30-80	30	46	50.3
remont	1-80	80	45	47.3	0-65	30	30	32.8
emhi	12-125	--	80	75.0	20-50	35	35	36.0
eton	20-25	--	22.5	22.5	3-25	--	20	17.2

able 22.--*Number of responses concerning problems in obtaining logs by type of firm and region for Idaho's forest products industry, 1973*

	Sawmills, plywood and chip mills						Cedar		Post/pole		
	Region						Region		Region		
Response	I	II	III	IV	V	VI	I	II	I-III	IV-VI	Total
oo large sales	4	2	4	1	4	7	2	6	--	--	30
ompetition	17	4	4	1	1	2	4	1	3	--	37
igh stumpage price	7	1	2	--	4	6	3	6	--	1	30
eather	6	6	--	--	--	1	--	9	2	1	25
nvironmental restrictions	1	1	--	1	--	6	--	--	1	--	10
orest Service restrictions	8	4	3	2	2	4	--	5	2	3	33
ack of raw material	5	1	7	--	--	--	5	1	7	6	32
inancing	2	1	1	--	--	1	--	--	--	--	5
ogging costs	1	--	1	--	1	3	--	--	--	--	6
isposal of waste material that could be used	--	--	1	--	--	--	--	2	1	1	5
ther	1	--	--	--	--	--	--	3	-	2	6
o problems	3	6	2	1	1	2	--	2	2	--	19
umber of firms not responding	7	7	1	1	--	3	--	2	1	--	22

Table 23.--*Sales of Idaho lumber and lumber products (M bd. ft.) by county and destination, 1973*

County of origin	Destination							
	Local	Idaho	Mont.	Eastern Wash.	Western Wash.	Eastern Ore.	Western Wash.	Calif.
Boundary	77	4,185	233	0	0	0	0	0
Bonner	5,933	16,865	123	13,949	8,205	6,540	8,744	2,017
Benewah	10,867	423	303	704	0	47	0	23
Kootenai	33,428	1,515	1,958	4,956		133	2,953	1,604
Shoshone	5,000	406	136	1,627		406		136
Region I	55,305	23,394	3,053	21,236	8,205	7,126	11,697	3,780
Clearwater	530	600		1,020				
Idaho	6,189	28,757	3,837	275	1,673	1,137	2,823	3,914
Latah/Lewis/ Nez Perce	2,573	6,395	3,821	11,238		588	515	1,322
Region II	9,292	35,752	7,658	12,533	1,673	1,725	3,338	5,236
Ada/Elmore	35,282					280		
Boise/Gem	37	3,047						6,018
Adams	22	31,680						
Valley	460	28,047				10		
Canyon/Washington	0	9,800			5,000			
Region III	35,801	72,574			5,000	290		6,018
Region IV	5,628	22						
Bannock/Caribou/ Franklin	769							
Bear Lake	590							
Region V	1,359							
Bonneville/Jefferson/ Madison								
Butte/Custer	1,498	575						
Fremont	4,645	360	129					
Lemhi	2,358	9,490	4,016					
Teton	277							
Region VI	8,776	10,225	4,145					
Total	116,161	141,967	14,856	33,769	14,878	9,141	15,035	15,034

(con.)

Table 23.--*Sales of Idaho lumber and lumber products (M bd. ft.) by county and destination, 1973*

					Destination				
County of origin	Utah	Wyo.	Other West	Mid. West.	East Coast	South	Canada	Unknown	Total
Boundary	0	2,985	0	35,820	13,180	5,970	0	0	62,450
Bonner	423	0	1,128	75,765	48,148	11,352	846	8,550	208,888
Benewah	0	0	7,985	48,559	25,771	3,452	17	0	98,181
Kootenai	1,095		51,096	92,415	84,483	22,704	2,189		300,529
Shoshone	136		136	32,987	12,078	4,615	271		57,954
Region I	1,654	2,985	60,345	285,546	183,660	48,093	3,353	8,550	727,982
Clearwater			4,320	12,204	25,000			14,069	57,743
Idaho	627	419	9,672	83,586	34,746	21,010	187	28,331	227,183
Latah/Lewis/ Nez Perce	1,029			183,873	108,814	48,135	1,103		369,406
Region II	1,656	419	13,992	279,663	168,560	69,145	1,290	42,400	654,332
Ada/Elmore	140			5,590	3,040	1,400			47,732
Boise/Gem					51,152			214,772	275,026
Adams									51,702
Valley								32,271	60,788
Canyon/Washington		1,400		2,100	700				19,000
Region III	1,540		2,100	6,290	56,192	1,400		247,043	434,248
Region IV		30	4,136					1,034	10,850
Bannock/Caribou/ Franklin	663								1,432
Bear Lake	1,860	500						2,001	4,951
Region V	2,523	500						2,001	6,383
Bonneville/Jefferson/ Madison			1,696		32,219				33,915
Butte/Custer	667		3,701	4,670					10,911
Fremont	5,275	6	10,500	26,775	5,250	3,150			56,088
Lemhi	5,780	790	6,300	4,266					33,000
Teton	360								637
Region VI	12,082	796	22,197	35,711	37,469	3,150			134,551
Total	19,455	4,730	102,770	607,210	445,881	121,788	4,643	301,028	1,968,546

Table 24.--*Costs and returns for lumber and lumber products manufacturers in Idaho, 1973*

Expenses and revenues	Average per firm	Average value per M bd. ft.
Gross revenue (all products sold)	$3,908,938.47	$220.74
Cash expenses		
Wages and salaries	688,433.60	38.87
Raw materials	1,445,838.43	81.65
Rentals	26,962.00	1.52
Repairs	79,763.20	4.50
Insurance	49,839.90	2.81
Marketing expense	13,176.10	.74
Transportation	62,106.83	3.51
Contract labor	167,985.20	9.49
Operating expenses	73,838.63	4.17
Supplies	103,018.57	5.82
Depreciation and taxes	43,841.63	2.48
Miscellaneous	30,333.70	1.17
Subtotal	$2,785,137.79	$157.27
Net cash income	1,123,800.66	63.46
Average value of inventory January 1, 1974	$2,804,073.42	
Average number of board feet used (M bd ft)	17,708	

Table 25.--*Sales of Idaho post/pole and cedar products by destination, 1973*

	Sales								
Destination	Posts (number)	Poles (number)	Shakes (squares)	Cedar posts (number)	Cedar rails (number)	Cedar pickets (bundles)	Cedar fencing (pieces)	Cedar shingles (bundles)	Mine props (number)
Idaho	240,476	117,542	13,900	63,190	30,000		33,200	1,800	
Montana	1,729	966	720	80			3,200		
Eastern Washington	110,100	29,320	7,095				3,200		
Western Washington			5,000						
Eastern Oregon		422							
Western Oregon		30,429		8,571	7,333				
California	453,816	7,923		9,950	10,000				
Utah	4,320	2,852							25,000
Wyoming	1,729	1,387	770	4,950			3,200		
Other Western States	75,470	76,328	2,400	1,330			175,000		
Mid-west	1,460	16,388	1,845	84,800	120,000	200	3,200		
East Coast		5,210	5,600	65,000	130,000	60,000			
South				5,000	10,000				
Canada	73,000								
Unknown	88,320	12,430							
Total	1,050,921	301,197	37,330	344,871	307,333	60,200	221,000	1,800	25,000
Number of firms reporting	15	16	11	10	6	2	3	1	1

Table 26.--*Costs and returns for post and pole plants in Idaho, 1973*

Expenses and revenues	Average per firm	Average value per M bd. ft.
Gross revenue	$407,269.38	$180.27
Cash expenses		
Labor	136,439.63	60.39
Raw materials	157,259.50	69.61
Repairs	16,631.88	7.36
Insurance	9,164.00	4.06
Marketing expense	2,062.50	.91
Transportation	6,087.50	2.70
Contract labor	38,228.25	16.92
Operating expense	14,264.13	6.31
Supplies	12,617.13	5.58
Preservatives	7,212.50	3.19
Depreciation and taxes	325.00	.14
Subtotal	$400,292.02	$177.17
Net cash income	6,977.36	3.10
Average inventory value January 1, 1974	$538,791.14	
Average quantity processed (M bd ft)	2,560	

Table 27.--*Costs and returns for cedar product manufacturers in Idaho, 1973*

Expenses and revenues	Average per firm	Average value per M bd. ft.
Gross revenue	$331,643.75	$178.54
Cash expenses		
Wages and salaries	$ 97,375.00	$ 52.42
Raw materials	139,625.00	75.17
Repairs	22,669.75	12.20
Insurance	497.38	.27
Marketing expense	8,185.50	4.41
Transportation	35,017.50	18.85
Contract labor	1,250.00	.68
Operating expenses	1,648.38	.89
Supplies	265.00	.14
Depreciation and taxes	375.00	.20
Miscellaneous	6,262.50	3.37
Subtotal	$313,171.00	$168.60
Net cash income	$ 18,472.75	$ 9.94
Average inventory value January 1, 1974	$ 86,166.66	
Average quantity processed (M bd. ft.)	1,858	

Table 28. [illegible] of residues produced by Idaho's forest products industry and [illegible]

Type of residue	Number of firms reporting	Fuel	Pulp	Board products	Sold	Burned	Bedding	Other	Unknown	Total
Pulp chips	43	--	864,605	--	--	-	-	--	-	864,605 (3,587,111 m^3)
Particle board chips	2	-	--	17,400	-	-	-	--		17,400 (98,584 m^3)
Coarse chips	1	-	1,558	--		-	-	-	--	1,558 (15,816 m^3)
Bark	8	217,165	--		8,100	21,150	--	-	53,600	300,015 (1,699,771 m^3)
Log trim	5	6,200	6,000		--	--	-	15,250	-	27,450 (155,177 m^3)
Sawdust	17	86,183	64,392	-	-	5,238	5,850	-	42,780	204,443 (1,135,509 m^3)
Shavings	11	25,121	1,468	1,000	--	5,650	10,150	17,576	--	64,268 (364,014 m^3)
Sander dust	1	-	-	-	-	663	-	-	-	663 (3,755 m^3)
Total (million meters^3)	-- --	334,979 (1.897)	941,021 (5.330)	21,100 (0.121)	8,100 (0.018)	31,001 (0.176)	16,000 (0.079)	32,826 (0.186)	95,780 (0.542)	1,479,398 8.379

Table 29.--*Units (200 ft^3, 5.66 m^3) of pulp chips produced by Idaho sawmills by area, 1973*

Area[1]	Number of firms reporting	M bd. ft. used	Units of chips produced	Units produced per firm	Units produced per M bd. ft. used
Region I	23	484,541	291,530	12,675	0.6017
Region II	11	550,545	445,998	40,545	0.8101
Region III	6	212,289	87,424	14,571	0.4118
Region IV-VI	3	65,144	39,651	13,217	0.6087
Total	43	1,312,519	864,603 (4,897,111 m^3)	20,107 (113,886 m^3)	0.6587 (3.731 m^3)

[1] Composition of regions identified in table 16.

Table 50.--Origin and destination of residues (in units of 200 ft³, 5.66 m³) from Idaho's forest products industry by county, 1973

County of origin	Destination Idaho	Eastern Wash.	Western Wash.	Eastern Ore.	Western Ore.	Montana	Unknown	Total
Boundary	0	1,770	8,850	3,540	0	3,540	0	17,700 (100,255 m³)
Bonner	-	3,727	92,068	0	6,000	11,802	4,500	118,097 (668,901 m³)
Benewah	62,154	0	82,700	0	0	0	738	145,592 (824,633 m³)
Kootenai	55,987	11,070	10,392	--	-	2,688	2,160	82,297 (466,130 m³)
Shoshone	--	4,140	9,660	--	--	2,639	-	16,439 (93,110 m³)
Region I	118,141	20,707	203,670	3,540	6,000	20,669	7,398	380,125 (2,153,028 m³)
Clearwater	64,769	--	--	--	--	--	13,315	78,114 (442,138 m³)
Idaho	100,186	--	--	--	-	--	--	100,186 (567,454 m³)
Latah/Lewis/ Nez Perce	320,894	7,118	--	--	--	--	--	328,312 (1,859,559 m³)
Region II	485,849	7,118	--	--	--	--	13,345	506,612 (2,869,450 m³)
Regions III, IV, V, and VI		13,774	12,551	11,805	--	1,300	60,375	129,805 (735,216 m³)
Total	603,990 (3,420,990 m³)	41,899 (237,316 m³)	216,221 (1,224,676 m³)	15,345 (256,834 m³)	6,000 (33,984 m³)	21,969 (124,432 m³)	81,118 (459,452 m³)	1,016,542 (5,757,694 m³)
Percentage of total	59.42	4.12	21.27	4.16	.59	2.16	7.98	100

APPENDIX B

SURVEY METHODS

SURVEY METHODS

Data for this study were obtained by interviewing forest products firms operating in Idaho during 1973. A master list of firms operating in Idaho was compiled from various published directories (Bundy 1970; Miller Freeman Publications 1973). This list was augmented from the list of firms interviewed by Williams (1964, 1967). Entries were checked by county extension agents and revised as necessary. Each identified firm was sent a questionnaire and subsequently interviewed by College of Forestry, Wildlife and Range Sciences personnel in the spring and summer of 1974. Of the 209 firms contacted, responses were not received from 15. Of the 15 nonrespondents, 10 were sawmills sawing less than 1,000 board feet, one was a chipper whose production was reported elsewhere, two were cedar processors, and two could not be located.

Several weaknesses in the data should be noted:

1. Some parts of the questionnaire were filled out more completely than others. Most firms answered questions concerning general operating characteristics and timber volumes used, but many either were not able or willing to provide the expense and revenue information.

2. Some of the larger firms operating plants at several locations did not provide all of the information requested on a plant-specific basis. Data provided for multiplant operations were adjusted to a plant-specific basis when possible. These adjustmen may have resulted in some error at the county level, but any biases were eliminated when county data were aggregated.

3. Many mills did not have records that would provide the detailed data requested. Therefore, the survey relied on memory and judgment.

4. Units of measure were not always uniform, particularly in the post/pole and cedar businesses. Therefore volumes were converted to a uniform unit of measure (Dilworth 1973; Idaho State Board of Vocational Education 1974).

Readers reviewing this publication should remember that the forest products industry is dynamic--established firms close and new firms start every year. The industry description, therefore, should be viewed as one instance--1973--in an industry of continual change. Readers should also know that in 1973, prices for timber and timber products were at an all-time high. This was followed by a period of depressed prices (late 1974 and 1975) and subsequent recovery (late 1976). This cyclical price movement affected every part of the forest products industry--the number of operating firms, volume of timber, costs, and returns. Therefore, any extrapolation of the 1973 finding to other years should be done cautiously.

Godfrey, E. Bruce, Ervin G. Schuster, and Enoch F. Bell.
1980. Idaho's forest products industry, 1973. USDA For. Serv. Gen. Tech. Rep. INT-80, 42 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

A census of the Idaho forest products industry in 1973 showed that almost two billion board feet of timber was used by the industry in that year. Sawmills processed 70 percent of this amount and 45 percent of it was supplied by the USDA Forest Service. Most of the lumber, plywood, veneer, and cedar products were shipped to the eastern United States. Other characteristics discussed in the report include the number, production, location, equipment, employment, and ownership of firms with their species, source, and quantities of raw materials including residues.

KEYWORDS: sawmills, residues, employment, post and poles, cedar products.

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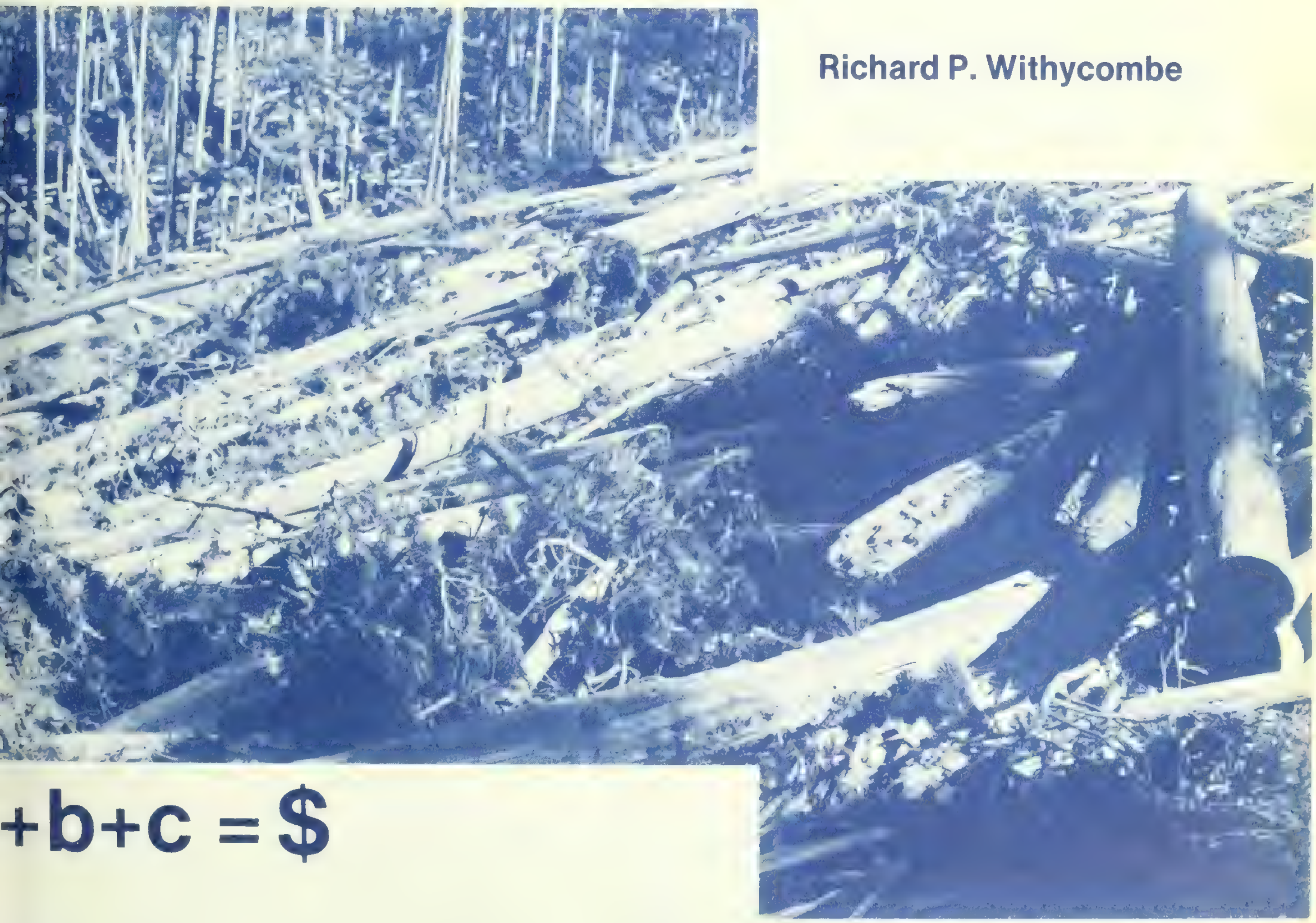

Richard P. Withycombe

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RESEARCH SUMMARY

Forest residues remaining after harvest are often technically suited for some fiber or solid wood product, but often the costs of removing these materials are judged to be greater than their value. Removal costs can be highly variable and little cost information is available that can be applied to residues.

A model is presented that determines cost per unit of harvesting wood residues. In deriving these costs such independent variables as skidding distance, volume per turn, and piece size are considered. Harvesting methods in the model include hand or mechanical felling, cable or ground skidding, chipping in woods, or roundwood logging.

Conversion factors and cost deflation factors are provided and, along with the independent variables, enable computation of residue harvest costs for a specific situation. Cost data are presented in a series of tables from which total costs can be summed.

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DATA REQUIREMENTS FOR USE OF THE COST TABLES ....

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- Diameter ....
- Yarding Distance ....
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EXAMPLES OF THE MODEL'S APPLICATION ....

RESIDUE COLLECTION COST TABLES ....

PUBLICATIONS CITED ....

ADDITIONAL REFERENCES ....

- Mechanical Felling and Limbing ....
- Cable Yarding ....
- Hauling ....
- Chipping ....

NOTES ON THE CONSTRUCTION, USE, AND LIMITATIONS OF THE RESIDUE COLLECTION COST TABLES ....

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United States
Department of
Agriculture

Forest Service

Intermountain
Forest and Range
Experiment Station
Ogden, Utah
84401

General Technical
Report INT-81

February 1982

Estimating Costs of Collecting and Transporting Forest Residues in the Northern Rocky Mountain Region

Richard P. Withycombe

TRODUCTION

During the past decade there has been a growing con-
rn among forest managers and the public about what
do with the large amounts of unused wood in our
rests. These forest residues consist of the wood fiber
maining after removal of the material that will make a
mmercial product, as well as material that will be left
hen unlogged sites are harvested. On land that has
en logged, forest residues are tree limbs, tree tops,
oken trunks, cull logs, undersize trees, and stumps. On
harvested land, forest residues are mostly standing
ead, down dead, and dying trees, suppressed trees and
usable species. Most of the material is sound wood, so
e constantly recurring question is: Why are these
aterials not being used to help satisfy the world's grow-
g demand for wood?

The reasons they are not being used are mostly eco-
mic. Forest residues are not utilized because collec-
n and transportation costs are judged to be greater
an the value of the materials. As a general rule, we can
sume that the logging and forest industries will take
y material that will return a profit and will leave any
at does not. This general rule may be modified by such
ctors as pricing policies that charge for marginal
aterials or contracts that require removal of all material.

The difference between the value of forest residues
d the cost of collecting them can be extremely vari-
le. Small-volume widely scattered residues in remote
eas are expensive to collect, but the cost of collecting
ncentrated residues near the point of end use may be so small that a slight increase in the market value of the residue would make utilization profitable.

When decisions are to be made concerning the possible use of forest residues, it is important that estimates of the material collection and transportation costs be available. The residue collection cost tables presented here are estimates of the costs for collecting and transporting the types of forest residues common to the Northern Rocky Mountain region. The tables were developed from average costs over a broad range of variable conditions, and should be used only for purposes of estimation. For ease of use in estimating costs, tables 1 through 12 are grouped together in the section entitled "Residue Collection Cost Tables."

METHOD OF STUDY

Nearly all data used to construct the residue cost tables are from published sources. During the past 10 to 15 years, a great deal of information has been collected and published about the costs of logging. Many of the operations required in the harvesting of residues are the same as those in conventional logging; so logging costs can be used to simulate residue costs. The primary difference between the two is in distribution of piece size, with residues tending to be both smaller and more variable. The units of measurements are also different; logs are measured in board feet or occasionally in cubic feet, and residues are measured by cubic volume or by weight.

The data sources can be categorized into three groups: (a) timber appraisal data, developed by the two major public landholders, the Forest Service and the Bureau of Land Management; (b) special studies of logging equipment or systems usually published as monographs; and (c) case histories of specific operations reported in the various trade journals.

When available, the time required for each operation in the harvesting process was obtained. Time estimates from the various sources were converted as necessary to common units of measurements and then combined into a single time estimate. Methods used for combining the data from various sources were variable and were based primarily on judgment. Operation costs were obtained from the same sources and combined in the same manner as the time estimates after first being converted to a common time base of 1978 prices. The seven tables that comprise the cost model have been simplified by using average values for many of the variables affecting cost, but some variables have such a great effect on cost that average values could not be used. Such site-specific information as piece size and skidding distance is required.

USE OF THE COST MODEL

To determine which tables are to be used, the source and type of residue must be identified. Most of the residue in the Northern Rocky Mountain region can be classified either as logging residues or as standing dead trees. In the Northern Rockies, which include most of western Montana and northern Idaho, the majority of the residues are a direct result of logging operations. To the south, southern Idaho and western Wyoming, the predomina residues are standing dead pines, the result of mount pine bark beetle epidemics.

Figure 1 shows the sequence of cost table use for each of the two major residue types. One must detern residue type, ground slope, and availability of adequa landings to choose the correct tables.

The choice between hand felling and mechanical fe ing of standing dead trees is determined by both the slope and the total volumes of residues to be harveste Mechanical fellers are generally not cost effective at slopes above 15 percent, so hand felling should be assumed on slopes above 15 percent. Even on flat ground, mechanical fellers are economical only if the volumes to be harvested are large enough to utilize th full capacity of the fellers over an extended period. O mechanical feller can produce about 10,000 cunits (28 300 m^3) per year, and mechanical felling should be assumed only if the total annual harvest of dead resic will be enough to use at least 75 percent of the feller' capacity. Hand felling costs are shown in table 1, anc mechanical felling costs in table 2.

The choice between ground skidding or cable yard is dependent on the slope of the ground. For sites wi an average slope of 30 percent or less and a maximu slope of 40 percent, ground skidding (table 3) should used. If the average slopes are greater than 30 perce then cable yarding (table 4) is needed. For logging re dues, the method used for commercial logging can b assumed to be the correct choice.

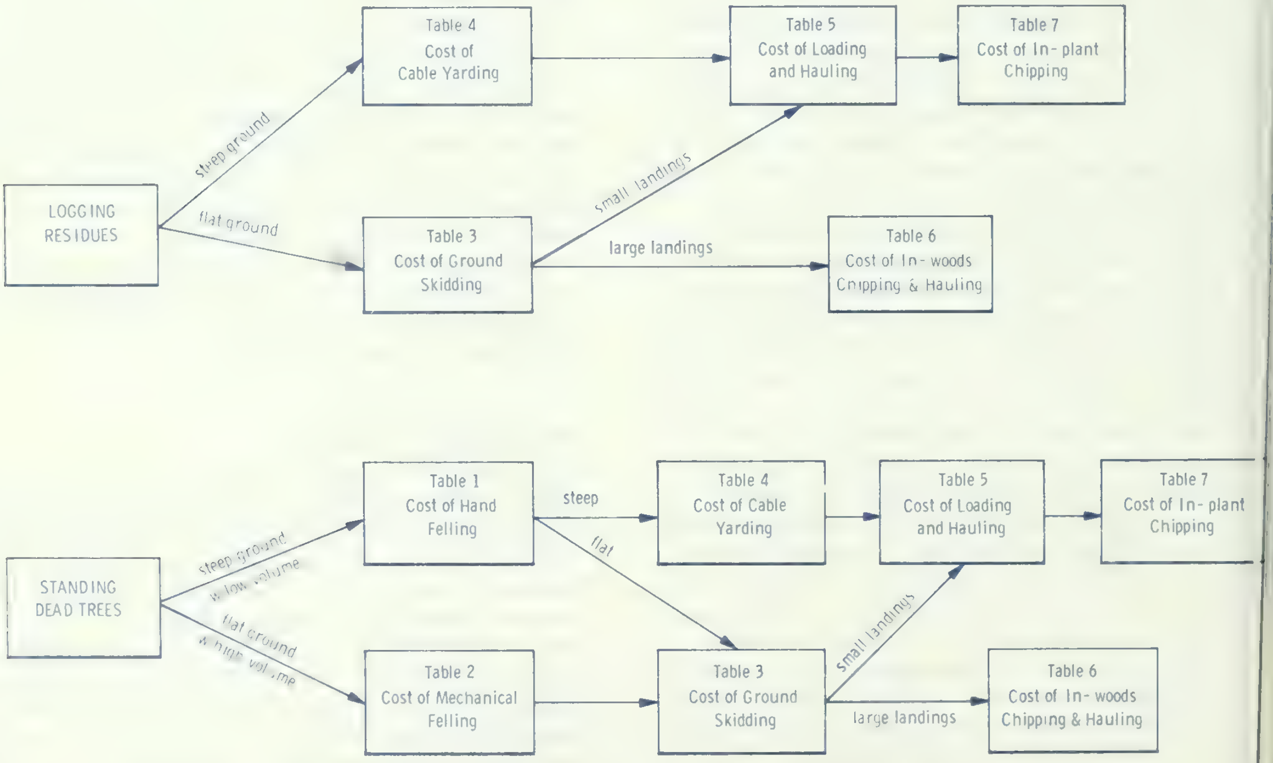

LOGGING RESIDUES
steep ground
flat ground
Table 4 Cost of Cable Yarding
Table 3 Cost of Ground Skidding
small landings
large landings
Table 5 Cost of Loading and Hauling
Table 7 Cost of In-plant Chipping
Table 6 Cost of In-woods Chipping & Hauling
STANDING DEAD TREES
steep ground & low volume
flat ground & high volume
Table 1 Cost of Hand Felling
Table 2 Cost of Mechanical Felling
steep
flat
Table 4 Cost of Cable Yarding
Table 3 Cost of Ground Skidding
small landings
large landings
Table 5 Cost of Loading and Hauling
Table 7 Cost of In-plant Chipping
Table 6 Cost of In-woods Chipping & Hauling

Figure 1.—Table selection guide for estimating costs of collecting logging residues or standing dead timber.

The third choice in the table selection is whether the iterial is to be chipped in the woods or to be hauled as ces and chipped at a central plant. The choice is arbiry to some degree, depending only on the preference the end user. Small pieces tend to make in-woods ipping more economical and large pieces may necessie in-plant chipping. The primary consideration will be e availability of adequate landing space. Effective utiliion of in-woods chipping machinery requires large dings with a flat landing of about 75 ft by 150 ft being st. If the landing space is not adequate, the chipping sts may be several times those shown in the cost ole. Since large landings are not common in the mounns of Montana and northern Idaho, estimates for these ions should assume that the chipping will be done in nt.

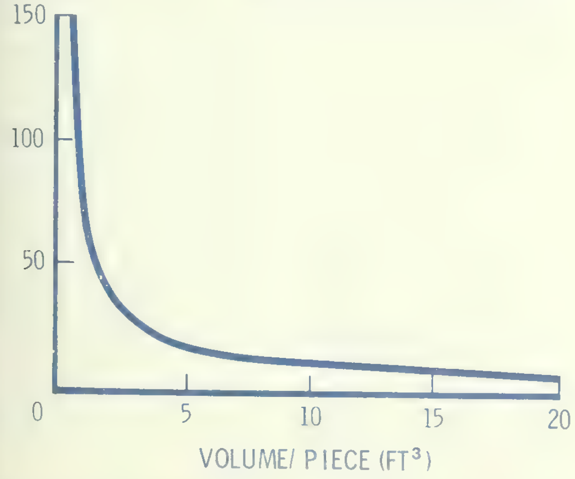
TA REQUIREMENTS R USE OF THE COST TABLES

ce Size

The costs of ground yarding, cable yarding, log load, and log hauling are heavily influenced by the size of residue material. The costs are much greater for aller pieces, but the relationship between costs and e is not linear. Figure 2 shows the cost per cunit (see le 11 for definition) for ground skidding a distance of ft (91 m). The cost rises sharply with decreasing ce size, so that costs based on average piece size uld be understated. The example below shows the dding cost properly weighted for piece size.

esidue	Piece size		Cost to skid 300 ft	
ercent	*Ft³*	*m³*	*$/cunit*	*$/m³*
30	2	0.06	36.80	12.99
50	10	.28	7.40	2.61
20	50	1.41	4.90	1.73
ghted average	15.6	.44	15.72	5.55

ne skidding cost for each size piece is separately read m table 3 and averaged using the piece-size percentes as weights, the expected average cost is $15.72 per nit. If the size is first averaged using the same weights, and the resulting average piece size of 15.6 ft³ (0.44 m³) is used to determine the average cost, then the apparent cost is only $4.90/cunit ($1.73/m³) since the cost is constant above 15 ft³ (0.42 m³) per piece.



ure 2.—The cost per cunit for ground lding a one-way distance of 300 feet.

Because of the nonlinear relationships, average piece size should be used only if the residues are quite uniform in size. Lodgepole pine killed by *Dendroctonus ponderosae* Hopkins (mountain pine beetle) is often surprisingly uniform over large areas; so use of an average size may be justified. Logging residues, however, usually contain a wide variety of sizes. The various sizes should be grouped into three or four categories and the costs of yarding and loading determined separately for each by using the average size within each category to read the tables. The resulting costs can then be averaged as shown in the above example.

The piece size in the cost tables is expressed in cubic feet, while most data will be in terms of diameter and length. Table 10 can be used to convert from length and large end diameter (d.b.h. for full tree) to approximate cubic-foot volumes. The volumes shown include bark, which for the typical Rocky Mountain types will average about 15 percent of the total volume.

Diameter

The cost tables for both hand felling (table 1) and mechanical felling (table 2) require the diameter at breast height (d.b.h.). As with piece size, the relationship between cost and d.b.h. is not linear; it is a curve that rises sharply with decreasing diameter. If the residues to be felled show a wide variation in size, the resource should be separated into several size categories, with separate cost estimates for each, using the weighting techniques described for piece size. If the residues are relatively uniform, however, the use of an average diameter will cause no problems. Most of the residues in the Rocky Mountain region that will require felling are either pine killed by the mountain pine beetle or overstocked stands of suppressed timber, and both types are usually uniform in size.

Yarding Distance

The distance the material must be moved is a major factor in determining the ground-skidding cost. The relationship between the cost and the distance is linear; so average yarding distance can be used. The average yarding distance, calculated from the geometry of the site, is preferred, but a reasonable approximation can be obtained for many sites by figuring the average yarding distance as two-thirds of the maximum distance (U.S. Department of the Interior, Bureau of Land Management [BLM] 1977). If actual yarding distances are not available, the reported average yarding distance of 600 ft for western Montana can be used (USDA Forest Service 1978).

The yarding distance also affects the cost of cable yarding, but because the cost differences are rather small, they have been omitted from table 4 to reduce the size of the table. The costs shown in table 4 apply to short or moderate yarding distance (1,000 ft or 305 m maximum). For distances of 1,000 to 2,000 ft (305 to 610 m), the costs shown in table 4 should be increased by 20 percent. The table should not be used for distances over 2,000 ft (610 m).

Haul Distance

The cost tables for loading and hauling (table 5) and chipping and hauling (table 6) require the one-way haul distance between the harvest site and the point of use. The tables were based on the assumption that 10 percent of the distance will be on dirt roads, 20 percent on gravel roads, and 70 percent on paved roads. It is assumed that a portion of the haul will be on public roads that have load weight limitations. If local conditions vary greatly from the assumptions, an adjustment of the tabled values may be necessary. The adjustments are detailed in the section entitled "Notes on the Construction, Use, and Limitations of the Residue Collection Cost Tables."

EXAMPLES OF THE MODEL'S APPLICATION

Example A: High volume harvest of dead lodgepole pine.

For this example, it is assumed that the site is on relatively flat ground with large landings available. The material is relatively uniform in size, with an average d.b.h. of 10 inches (25.4 cm). The average skid distance is 400 ft (122 m) and the haul distance, 40 miles (64 km). The material is to be chipped in the woods without barking.

The average volume per piece obtained from table 10 is 16.3 ft³ (0.46 m³).

The appropriate cost tables are selected by reference to figure 1. The tables used and the cost per cunit are:

	Per cunit	Per m³
Table 2, mechanical felling, without limbing	$ 5.90	$ 2.08
Table 3, ground skidding	5.20	1.84
Table 6, in-woods chip and haul, not barked	18.54	6.54
Total cost	$29.64	$10.46

Example B: Low volume dead lodgepole on moderate slopes.

For this example, assume that the harvest site has slopes above 15 degrees, but less than 30 degrees. Adequate landings are available, so in-woods chipping is feasible. The trees are to barked before chipping, so the felling must include limbing. Ground skidding an average of 800 ft (244 m) is assumed. The material has a uniform 14-inch (36-cm) diameter and the haul distance is 20 miles (32 km).

From table 10, the volume per piece is 40 ft³ (1.13 m³). From figure 1, the relevant tables and the costs per cunit from each are:

	Per cunit	Per m³
Table 1, hand felling, with limbing	$ 5.30	$1.87
Table 3, ground skidding	6.30	2.22
Table 6, in-woods chip and haul, barked	15.98	5.64
Total cost	$27.58	$9.74

Example C: Logging residues on steep ground.

For this example, assume that the logging residues ha the following size distribution:

(a) 3- to 5-inch (8- to 13-cm) diameter,
8-ft (2.4-m) long, 20 percent of total
(b) 6- to 10-inch (15- to 25-cm) diameter,
16-ft (4.9-m) long, 50 percent of total
(c) 14- to 22-inch (36- to 56-cm) diameter,
24-ft (7.3-m) long, 30 percent of total

The material is all on ground with slopes of 30 perce or greater, located within 500 ft (152 m) of a logging ro The landings are small so in-woods chipping is not fea ible. The one-way haul distance is 60 miles (96 km). Th material is to be chipped for fuel; so barking is not required.

By using the average diameter for each size class, table 10 can be used to convert the size distribution to cubic feet.

(a)	0.5 ft³ (0.014 m³)	20 percent
(b)	4.4 ft³ (0.12 m³)	50 percent
(c)	35.9 ft³ (1.0 m³)	30 percent

Referring to figure 1, the relevant cost tables are:

Table 4, cable yarding
Table 5, loading and hauling
Table 7, in-plant chipping

Each of the three size categories is costed separat (Note: The tables are read to the closest value, withou interpolation.)

	Table 4	Table 5	Table 7	Total	Perc
	$Cunit				
(a) 0.5 ft³	769.00	34.55	6.25	809.80	2
(b) 4.4 ft³	101.00	19.01	6.25	126.26	5
(c) 35.9 ft³	17.2	14.20	6.25	37.65	3

Average cost weighted by percent $236.39/cunit ($83.45 m

This example illustrates one of the problems inher in estimating average costs for all residues in an are. Had a decision been made to leave the small materia and to remove only the material in the two larger size categories, the total volume would be reduced by onl percent, but the weighted average cost would be red to $93.03 per cunit ($32.82/m³), a reduction of 60 perc

RESIDUE COLLECTION COST TABLES

Tables that can be used to develop cost estimates for recovering forest residues are grouped in this section to facilitate use.

Table 1.—Cost of hand felling

D.b.h.		Felling only	Limbing only	Fell and limb
ches	*cm*		[1] *$/Cunit*	
4	10	37.20	57.10	94.30
6	15	15.30	23.90	39.20
8	20	8.00	9.60	17.60
10	25	4.00	6.30	10.30
12	30	2.70	4.20	6.90
14	36	2.10	3.20	5.30
16	41	1.70	2.60	4.30
18	46	1.40	2.20	3.60
20	51	1.20	1.90	3.10
24	61	.90	1.50	2.40
28	71	.80	1.20	2.00

o obtain $/m^3, multiply tabled entries by 0.353.

Table 2.—Cost of mechanical felling

D.b.h.		Fell only	Fell and limb
Inches	*cm*	[1] *$/Cunit*	
4	10	69.00	81.80
6	15	26.80	31.80
8	20	11.10	13.20
10	25	5.90	7.00
12	30	3.50	4.20
14	36	2.40	2.90
16	41	1.70	2.10
18	46	1.30	1.50
20	51	1.00	1.20

[1] To obtain $/m^3, multiply tabled entries by 0.353.

Table 3.—Cost of ground skidding

Volume per piece		Volume per load[1]		One-way skidding distance											
				Feet											
				50	100	150	200	300	400	500	600	800	1,000	2,000	3,000
				Meters											
				15	30	46	61	91	122	152	183	244	305	610	914
Ft^3	*m*^{3}	*Ft*^{3}	*m*^{3}	[2] *$/Cunit*											
0.5	0.01	5	0.1	125.6	130.0	134.2	138.4	147.0	155.6	164.2	172.8	190.0	207.2	293.2	379.2
1.0	.03	10	.3	62.8	65.0	57.1	69.2	73.5	77.8	82.1	86.4	95.0	103.6	146.6	189.6
1.5	.04	15	.4	41.9	43.3	44.7	46.1	49.0	51.9	54.7	57.6	63.3	69.1	97.7	126.4
2.0	.06	20	.6	31.4	32.5	33.6	34.6	36.8	38.9	41.1	43.2	47.5	51.8	73.3	94.8
3.0	.08	30	.8	20.9	21.7	22.4	23.1	24.5	25.9	27.4	28.8	31.7	34.5	48.9	63.2
4.0	.11	40	1.1	15.7	16.3	16.8	17.3	18.4	19.5	20.5	21.6	23.8	25.9	36.7	47.4
5.0	.14	50	1.4	12.6	13.0	13.4	13.8	14.7	15.6	16.4	17.3	19.0	20.7	29.3	37.9
10.0	.28	100	2.8	6.3	6.5	6.7	6.9	7.4	7.8	8.2	8.6	9.5	10.4	14.7	19.0
15.0 or over	.42	150	4.2	4.2	4.3	4.5	4.6	4.9	5.2	5.5	5.8	6.3	6.9	9.8	12.6

[1] Volume per load assumes ten pieces per load to maximum load of 150 ft^3.
[2] To obtain $/m^3, multiply the tabled entries by 0.353.

Table 4.—Cost of cable yarding[1]

Average piece size		Yarding cost	
Ft^3	*m*^{3}	*$/Cunit*	*$/m*^{3}
0.5	0.01	769	272
1.0	.03	390	138
1.5	.04	261	92
2.0	.06	197	70
3.0	.08	133	47
4.0	.11	101	36
5.0	.14	82	29
10.0	.28	43.2	15.2
15.0	.42	30.8	10.9
20.0	.57	24.8	8.8
25.0	.71	21.3	7.5
30.0	.85	19.3	6.8
40.0	1.13	17.2	6.1
50.0	1.42	16.0	5.6
60.0	1.70	14.0	4.9
70.0	1.98	12.4	4.4
80.0	2.26	11.1	3.9
90.0	2.55	10.1	3.6
100.0	2.83	9.3	3.3

[1] For yarding distances of 1,000 to no more than 2,000 ft, increase the costs shown by 20 percent.

Table 5.—Cost of loading and hauling

Average volume per piece		One-way haul distance												
		Miles												
		5	10	15	20	25	30	40	50	60	70	80	90	100
		km												
		8	16	24	32	40	48	64	80	97	113	129	145	161
Ft^3	m^3	[1]\$/Cunit												
0.5	0.01	20.7	22.1	23.3	24.2	25.7	27.0	29.6	32.2	34.6	36.8	39.1	41.2	43.2
1.0	.03	17.6	18.6	19.6	20.6	21.8	22.9	25.2	27.5	29.6	31.6	33.5	35.4	37.2
1.5	.04	15.1	15.9	16.8	17.7	18.8	19.8	21.8	23.9	25.7	27.6	29.3	31.0	32.6
2.0	.06	13.2	14.0	14.8	15.6	16.5	17.5	19.3	21.2	22.8	24.5	26.1	27.6	29.0
3.0	.08	11.7	12.4	13.2	13.9	14.8	15.7	17.4	19.1	20.7	22.2	23.7	25.1	26.5
4.0	.11	10.6	11.2	12.0	12.7	13.5	14.3	15.9	17.5	19.0	20.4	21.8	23.1	24.4
5.0	.14	9.9	10.6	11.3	11.9	12.7	13.5	15.1	16.6	18.0	19.4	20.7	22.0	23.2
10.0	.28	8.4	9.0	9.7	10.4	11.1	11.9	13.4	14.8	16.2	17.5	18.8	20.0	21.2
15.0	.42	7.8	8.4	9.1	9.8	10.5	11.3	12.8	14.2	15.6	16.9	18.2	19.4	20.6
20.0	.57	7.5	8.1	8.7	9.4	10.1	10.9	12.4	13.9	15.2	16.6	17.8	19.0	20.2
25.0	.71	7.1	7.7	8.4	9.0	9.8	10.6	12.0	13.5	14.9	16.2	17.5	18.7	19.9
30.0	.85	6.8	7.4	8.1	8.7	9.5	10.2	11.7	13.2	14.6	15.9	17.2	18.4	19.6
40.0	1.13	6.4	7.0	7.7	8.3	9.1	9.9	11.4	12.8	14.2	15.5	16.8	18.0	19.2
50.0	1.42	6.1	6.7	7.4	8.0	8.8	9.6	11.1	12.5	13.9	15.2	16.5	17.7	18.9
60.0	1.70	5.9	6.5	7.2	7.8	8.6	9.4	10.8	12.3	13.7	15.0	16.3	17.5	18.7
70.0	1.98	5.8	6.4	7.0	7.7	8.4	9.2	10.7	12.2	13.5	14.8	16.1	17.3	18.5
80.0	2.26	5.6	6.2	6.9	7.5	8.3	9.0	10.5	12.0	13.4	14.7	16.0	17.2	18.4
90.0	2.55	5.4	6.0	6.7	7.4	8.1	8.9	10.4	11.9	13.2	14.6	15.8	17.0	18.2
100.0	2.83	5.3	5.9	6.6	7.2	8.0	8.8	10.2	11.7	13.1	14.4	15.7	16.9	18.1

[1] To obtain \$/m^3, multiply tabled entries by 0.353.

Table 6.—Cost of in-woods chipping[1] and hauling

One-way haul distance		Barked chips[2]	Not barked chips[2]
Miles	km	[3]\$/Cunit	
5	8	13.18	11.37
10	16	14.05	12.24
15	24	15.04	13.23
20	32	15.98	14.17
25	40	17.09	15.28
30	48	18.19	16.38
40	64	20.35	18.54
50	80	22.51	20.70
60	97	24.49	22.68
70	113	26.41	24.60
80	129	28.28	26.47
90	145	30.03	28.22
100	161	31.78	29.97

[1] Chipping only costs are: barked, \$9.04/cunit; not barked, \$7.23/cunit.

[2] If the residues are to be barked prior to chipping, table 1 or 2 (if used) must provide for limbing. If the residues are not to be barked, and thus contain bark in the chips, limbing is not required.

[3] To obtain \$/m^3, multiply tabled entries by 0.353.

Table 7.—Cost of in-plant chipping

	\$/Cunit	\$/m^3
Chip only[1]	6.25	2.20
Handling costs[2]	6.25	2.20
Total	12.50	4.40

[1] Chip-only costs include chipper, labor, power, and limited-yard handling.

[2] Handling costs include barking, bark and chip handling and storag and screening of chips.

Table 8.—Cost of loading

Average volume per piece		Weight of full load		Loading cost	
Ft^3	m^3	1,000 pounds	1,000 kg	\$/Cunit	\$/m^3
0.5	0.01	30	14	16.1	5.7
1.0	.03	34	15	13.3	4.7
1.5	.04	38	17	11.2	4.0
2.0	.06	42	19	9.7	3.4
3.0	.08	45	20	8.4	3.0
4.0	.11	48	22	7.5	2.6
5.0	.14	50	23	7.0	2.5
10.0	.28	52	24	5.6	2.0
15.0	.42	52	24	5.0	1.8
20.0	.57	52	24	4.6	1.6
25.0	.71	52	24	4.2	1.5
30.0	.85	52	24	3.9	1.4
40.0	1.13	52	24	3.6	1.3
50.0	1.42	52	24	3.3	1.2
60.0	1.70	52	24	3.1	1.1
70.0	1.98	52	24	2.9	1.0
80.0	2.26	52	24	2.8	1.0
90.0	2.55	52	24	2.6	.9
100.0	2.83	52	24	2.5	.9

Table 9.—Cost of hauling

ne-way istance		Assumed values				Round-trip time	Cost per trip
		Dirt road		Gravel road			
Miles	km	Miles	km	Miles	km	Minutes	Dollars
5	8	2	3	2	3	71	29.6
10	16	2	3	2	3	86	35.9
15	24	2	3	3	3	103	43.0
20	32	2	3	4	5	119	49.6
25	40	2.5	4	5	6	138	57.6
30	48	3	5	6	8	157	65.5
35	56	3.5	6	7	10	175	73.0
40	64	4	6	8	11	194	80.9
45	72	4.5	7	9	13	212	88.4
50	80	5	8	10	14	231	96.3
55	89	5	8	11	16	248	103.4
60	97	5	8	12	18	265	110.5
65	105	5	8	13	19	281	117.2
70	113	5	8	14	21	298	124.3
75	121	5	8	15	23	315	131.4
80	129	5	8	15	24	330	137.6
85	137	5	8	15	24	345	143.9
90	145	5	8	15	24	360	150.1
95	153	5	8	15	24	375	156.4
00	161	5	8	15	24	390	162.6

ble 10.—Volumes[1] of selected stems and stem segments in typical Northern Rocky Mountain stands; cubic feet, including bark[2]

Large end diameter or d.b.h.		Tree segment length				
		Feet				
		8	16	24	32	
		Meters				Full tree
		2.4	4.9	7.3	9.8	
Inches	cm	[3]Cubic feet				
4	10	0.5	0.9	1.1	1.4	1.4
6	15	1.3	2.3	2.9	3.5	3.6
8	20	2.5	4.4	5.8	7.0	8.7
10	25	3.9	7.2	9.8	11.9	16.3
12	30	5.8	10.6	14.7	18.2	27.4
14	36	8.0	14.8	20.7	25.8	40.0
16	41	10.5	19.7	27.8	34.9	55.8
18	46	13.4	25.3	35.9	45.4	75.1
20	51	16.6	31.6	45.1	57.2	98.2
24	61	24.1	46.2	66.6	85.2	157.0
28	71	33.0	63.7	92.2	118.8	235.2
32	81	43.3	83.9	122.0	158.0	335.0

Volumes not listed may be calculated using Smalian's Rule. Table umes taper of 1 inch per 8 feet.

$$V = 0.005454 \frac{L \quad (D^2_S + D^2_l)}{2}$$

L = length in feet
D_S = small end diameter in inches
D_l = large end diameter in inches

[2]To obtain volume without bark, reduce the tabled values by 8 percent for gepole pine, or by 20 percent for other species.

[3]To obtain cubic meters, multiply tabled entries by 0.0283. For volumes listed, Smalian's Rule may be used. Table assumes taper of 0.9 cm per er of length.

$$V(m^3) = 0.00007854 \frac{L \quad (D^2_S + D^2_l)}{2}$$

L = length in meters
D_S = small end diameter in centimeters
D_l = large end diameter in centimeters

Table 11.—Residue conversions

Unit	Conversion
Cunit	= 100 ft³ of solid wood[1] = 2.83 m³ of solid wood ≅ 5,000 lb green weight ≅ 2,500 lb ovendry weight
b.d.u. (bone dry unit)	= 2,400 lb ovendry wood[1]
Cord	= 128 ft³ of stacked wood[1] ≅ 85 ft³ of solid wood ≅ 2,125 lb ovendry weight
b.d.t. (bone dry ton)	= 2,000 lb ovendry wood[1] = o.d.t. (ovendry ton)[1]
Unit	= 200 ft³ of chipped material[1] ≅ 75 ft³ of solid wood ≅ 3,750 lb green weight ≅ 1,875 lb dry weight
M bd. ft. (thousand board feet)	≅ 2 cunits of solid wood

[1]Definition of the unit. All other conversions employ one or more assumed values.

Table 12.—Cost inflators/deflators used in the construction of the residue cost tables

Year	Wholesale price index[1]	Conversion factor to 1978 basis
1965	96.6	2.17
1966	99.8	2.10
1967	100.0	2.10
1968	102.5	2.05
1969	106.5	1.97
1970	110.4	1.90
1971	113.9	1.84
1972	119.1	1.76
1973	134.7	1.56
1974	160.1	1.31
1975	174.9	1.20
1976	183.0	1.15
1977	194.2	1.08
1978	210.6	1.00

[1]The wholesale price index shown is the wholesale price index for all commodities published in "Business Statistics" by the U.S. Department of Commerce.

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NOTES ON THE CONSTRUCTION, USE, AND LIMITATIONS OF THE RESIDUE COLLECTION COST TABLES

Table 1. Cost of Hand Felling

The time required to hand fell dead trees was derived primarily from data provided by Adams (1967) and the USDI (1977) and was verified by comparison to experienced costs collected by the National Forest Region 1 timber appraisal group (USDA 1978). In the size range of 8- to 10-inches (20- to 51-cm) d.b.h., the sources are in close agreement, and the costs in table 1 can be expected to have an overall accuracy of plus or minus 20 percent. Beyond this range, the variation is much greater, especially for the small sizes. The table can be extrapolated to obtain costs for sizes somewhat greater than shown, but it should not be extended to smaller sizes. The cost shown for a 4-inch (10-cm) d.b.h. may differ from actual costs by as much as 50 percent; the error increases rapidly at smaller diameters. The costs shown for limbing include the cost to make one bucking cut to overall length.

Table 2. Cost of Mechanical Felling

The Woodlands Research Division of the Pulp and Paper Research Institute of Canada (PPRIC) and its successor organization, the Forest Engineering Research Institute of Canada (FERIC), have conducted and published extensive studies of mechanical tree harvesting systems during the past decade. The costs in table 2 are a combination of the time and cost estimates from 12 of the PPRIC and FERIC publications (Cottell 1977; Folkema 1977; Folkema and Novak 1976; Heidersdorf 1974, 1976; Powell 1971a, 1973, 1974a, 1974b, 1974c, 1975; Powell and Myhrman 1977).

Although the time required for mechanical felling is dependent on a number of variables such as slope, tree spacing, and tree size, the total variation between different systems was much greater than could be explained by any of the variables. The average reported time of 0.70 minute per tree without limbing and 0.83 minute per tree with limbing was therefore used to construct table 2. The hourly cost of operating a mechanical feller is also quite variable, but the variation possible for a single machine is much greater than the differences between the various machines. The FERIC and PPRIC reports show calculated costs under both favorable and unfavorable costs, and the midpoint between the two was used for table 2. The unfavorable costs are typically double the favorable costs, and these possible large variations in operation cost coupled with the variability in the operating times mean that there may be large differences between actual costs and those shown in table 2. The variation may exceed 50 percent. Low operating costs can be expected only if the entire system has sufficient support capacity to keep the harvester working full time over an extended period.

Table 3. Ground Skidding Cost

A number of extensive studies of the time required fo ground skidding have been made. Table 3 is based on time estimates obtained by combining the results of seven of them (Cottell, Winer, and Bartholomew 1971; Host and Schlieter 1978; Koger 1976; Legault and Powel 1975; McMorland 1977; Powell 1971b; Sampson and Dor nelly 1977). The studies were combined by using averag values for all variables except distance, which yielded a time estimate of T = 14.1 + 0.01D, where D is the one-way skid distance in feet and T is the round-trip time in minutes. The hourly cost of $25.80 for the skidder and operator is from USDI (1977). Table 3 was constructed b assuming that the load per skidder turn would be 10 pieces, but would not exceed 150 ft³ (4.2 m³). Under goo conditions, a grapple skidder could haul more than 10 small pieces; so the values in table 3 should be adjuste for a greater volume if appropriate.

Table 4. Cable Yarding Cost

The time required for cable yarding is dependent primarily on the piece size, with yarding distance and the number of pieces per turn having a much smaller effec For construction of table 4, all variable conditions exce piece size have been held constant at average values. The number of pieces per shift is estimated as N = (20 2V) for per-piece volumes of 0.4 to 50 ft³ (0.01 to 1.4 m³) equals volume per piece) and as N = (133 - 0.5V) for per-piece volumes greater than 50 ft³ (1.4 m³). The cost per day for the equipment and a four man crew is estimate as $800. The costs in table 4 should be used only for a relatively short yarding distance (to 1,000 ft [305 m]). Above 1,000 ft, the yarding distance, which was omitte from the tables, has a considerable effect on the total time; consequently, the costs in table 4 will be too low The tabled values should be increased by 20 percent fo distances of more than 1,000 ft, and the table should r be used for yarding distances of more than 2,000 ft.

Most cable yarding machines have been designed t handle large logs and are very inefficient when used fo small pieces. Although table 4 shows costs for the ful range of sizes used in the other tables, the very high c of cable yarding at average piece sizes of less than 15 20 ft³ (0.4 or 0.6 m³) precludes cable yarding as a reaso able alternative. In situations where steep slopes mak ground skidding impossible, the high cost of cable ya ing really means that the small residues are inaccessi to existing equipment. There is a trend toward the de ment of small cable yarding systems (Blackman 1977; Case and Sulter 1976) which will reduce the costs of yarding small pieces, but the cost reductions are unli to be enough to make cable yarding of small residues economically feasible.

ble 5. Loading and Hauling Cost

The costs of loading and of hauling logs or residue
eces have been combined in table 5. On-highway log
icks were assumed to have a maximum load of 52,000
unds (23 553 kg), or 1,040 ft³ (29 m³). For smaller pieces,
e assumed load was reduced because of the difficulty
loading many small pieces on a truck. At average
ece sizes smaller than 10 cubic feet (which amounts to
4 logs per load), the load size was steadily reduced to a
ad of 30,000 pounds (13 590 kg) for pieces averaging
ly 0.5 ft³ (0.01 m³). The loading time varies from 50
nutes per load for large pieces, to 125 minutes for very
all pieces. The combined cost of the truck and driver
d the loader and operator is $46 per hour.

The round trip time and the hauling cost are dependent
both the total distance and the type of roads. For con-
uction of table 5, it was assumed that dirt roads would
mprise 10 percent of the total distance, with a mini-
m of 2 mi (3 km) and a maximum of 5 mi (8 km); gravel
ads would comprise 20 percent of the total, with a mini-
m of 2 mi (3 km) and a maximum of 15 mi (24 km); and
t paved roads would comprise the remainder. For sig-
icant departure from these assumptions, the cost per
d should be modified by $1.30 for every mile of dirt
d greater or less than the assumed value ($0.81 per
) and by $0.75 for every mile of gravel road ($0.40 per
). The average cost for the log truck and driver is $25
hour whether operating or delayed.

ble 6. In-Woods Chipping and Hauling Cost

The cost of chipping residue material in the woods and
n hauling the chipped material in vans to a central
ation is one of the few costs of residue handling that
not heavily influenced by piece size. Portable chippers
have maximum size limits, but they are available in
es able to handle nearly all residue in the Rocky Moun-
n region. The production rate for in-woods chippers
erages 8.3 cunits (23 m³) per hour regardless of the
idue size and whether the material is barked or not.
e cost of the equipment is, however, about $75 per
ur with the barker and $60 without. This cost includes
chipper and operator and a front end loader with
erator to help with material supply to the chipper and
spot empty vans.

he chips are assumed to be hauled in 10-cunit (50,000
und) (28 m³ or 22 650 kg) capacity vans, which cost $35
hour. The cost includes an extra van which is filled at
landing while the loaded van is being hauled to the
l. The round trip times are the same as for log trucks.

arge variations from the costs shown in table 6 are
ssible. Under very good conditions, the cost may be
f that shown, whereas poor conditions might result in
sts several times those shown in table 6. The
uirements for effective chipping are a continuous
pply of material to the chipper and an adequate land-
to allow free movement of raw materials and the chip
s.

he chip vans may be unable to negotiate many of the
ging roads that present no problem to log trucks, and
y may not stand up to long hauls over rough roads. As a general rule, in-woods chipping should not be considered for mountainous country where the roads may have sharp switchbacks and where level landing space is at a premium.

Table 7. In-Plant Chipping Cost

The cost of chipping shown in table 6 includes the cost of a stationary chipper, with the necessary labor and power to produce chips from residues. It includes a limited amount of yard and chip handling, and chip storage. The cost of $6.25 per cunit ($2.20/m³) would be appropriate for residues that are to be used for fuel, or as a low grade filler in composite panels. If the chips are to be used for paper, an additional cost of $6.25 per cunit ($2.20 m³) is required for barking, bark and chip handling and storage, and screening of the finished chips.

Table 8. Loading Cost and Table 9. Hauling Cost

Tables 8 and 9 show the loading and hauling costs that were combined in table 5. There may be situations where adjustments to either the loading or the hauling costs are needed to account for local conditions, and these tables have been included to make such adjustments easier. For the assumptions used in constructing the tables, see the section on table 5.

Table 10. Volumes of Selected Trees or Tree Segments

The cubic foot volumes shown in table 10 were used in converting the data from the various sources to a common measurement of cubic feet. This table differs somewhat from the usual cubic foot table in that the measurements shown include bark and the diameter measurements are at the large end. The column headed "tree length" was derived from gross volume tables developed by Faurot (1977) by averaging the volumes for typical tree heights for the four common Rocky Mountain species: ponderosa pine, lodgepole pine, western larch, and Douglas-fir. To obtain volumes without bark, reduce the values in table 10 by 8 percent for lodgepole pine and by 20 percent for the others.

Table 11. Residue Conversions

Just as there are a number of scaling rules used for measuring logs, there are many ways to measure residues, and there will often be a need to convert from one system of measurement to another. Some of the measurement conversions follow directly from the definition of the units, but many of them depend on such things as the wood density or moisture content. The conversions shown in table 11 are based on assumed values for the types of residues likely to be found in the Northern Rockies and should not be used for other purposes.

Table 12. Cost Inflators/Deflators

The costs that are shown in tables 1 through 9 are based on published reports of studies conducted over the past decade. During that time, prices have changed dramatically; so a conversion of all cost data to a common time basis was required. There are many price indexes available for the purpose, but none of them are directly connected to the costs of forest harvesting. The Wholesale Price Index, which includes producer prices for all commodities, was selected as the index that would most closely approximate the cost of residue collection. All costs were converted to 1978 equivalents by first dividing the cost by the index for its year and then multiplying by the index for 1978.

It is suggested that any costs obtained from tables 1 through 9 be converted to the equivalent cost in the desired year. New values of the index are available from several sources, the most convenient probably being the "Survey of Current Business," which is published monthly by the U.S. Department of Commerce, Bureau of Economic Analysis. (The page and section number may vary, but one should look under Commodity Prices, subsection—Producer Prices.)

To convert the prices shown in the residue cost tables to a later year, divide the costs by 210.6 (the index for 1978) and multiply by the new price index.

Withycombe, Richard P.
1982. Estimating costs of collecting and transporting forest residues in the Northern Rocky Mountain Region. USDA For. Serv. Gen. Tech. Rep. INT-81, 12 p. Intermt. For. and Range Exp. Stn., Ogden, Utah, 84401.

A model is presented for computing the costs of harvesting forest residues, based on several key characteristics of the residues and the logging area. Costs per unit are presented in tabular form for several alternative harvesting methods.

KEYWORDS: harvesting, logging cost, forest residues, utilization, cost models

The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

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User's Guide to

AFFIRMS:

Time-Share Computerized Processing for Fire Danger Rating

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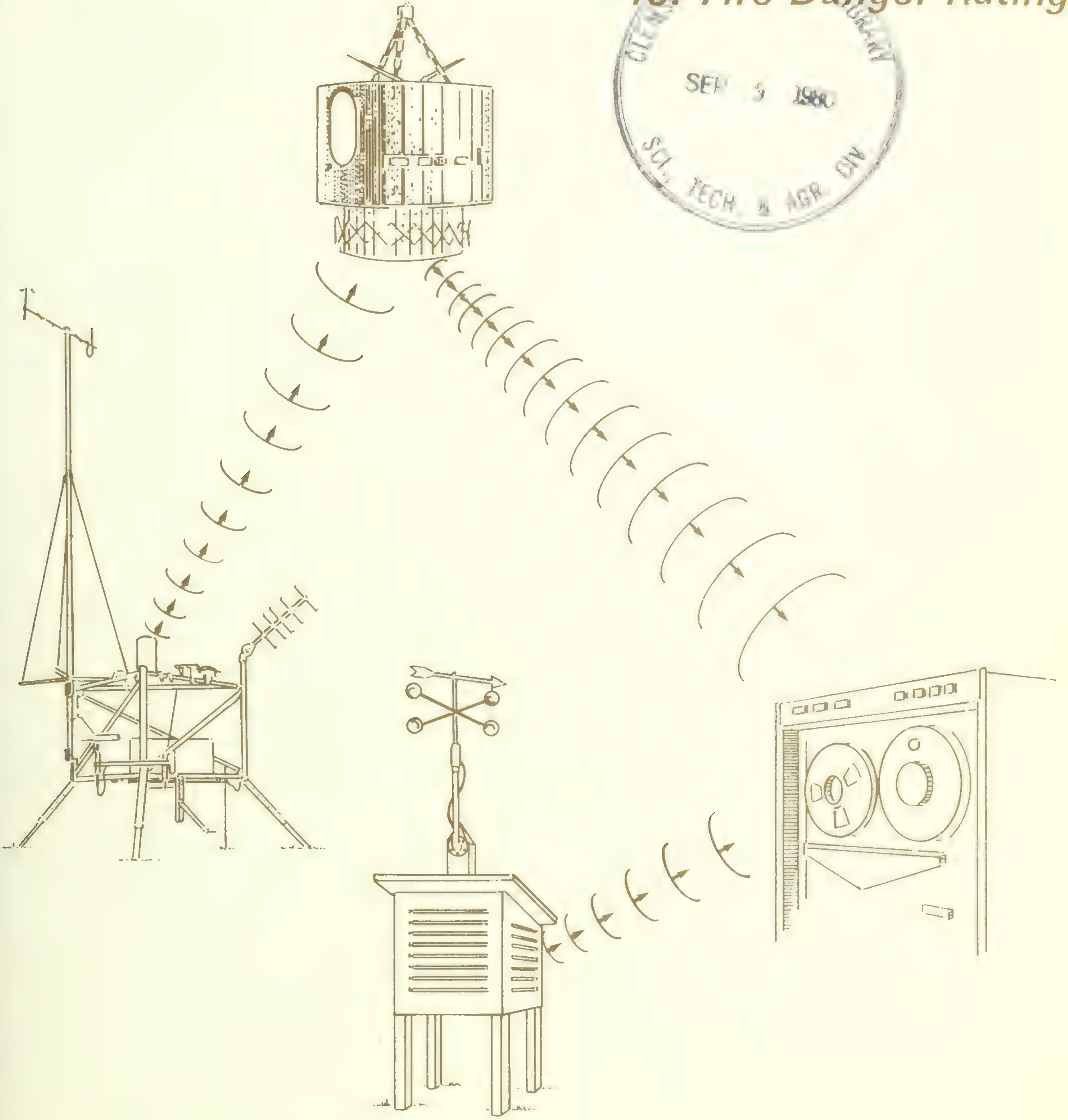

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INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
U.S. Department of Agriculture, Forest Service

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RESEARCH SUMMARY

This User's Guide is a comprehensive manual for persons accessing the 1978 version of National Fire Danger Rating System on AFFIRMS. AFFIRMS, the Administrative and Forest Fire Information Retrieval and Management System is a user-oriented, interactive computer program. Weather observations and fuels data are processed to produce a rating of probable forest fire danger in the form of fire danger indexes. Fuels and weather data are also automatically checked for errors and archived. Other program output includes narrative messages sent between users, and observed and forecasted weather. This version of the User's Guide to AFFIRMS supercedes the August 1975 version published as USDA Forest Service General Technical Report RM-15. The Guide is written in nontechnical language for persons without a computer background.

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User's Guide to AFFIRMS: Time-Share Computerized Processing for Fire Danger Rating

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DSPC	Display user defined weather, fuels, and or ratings . . .	1.5.2.1
DSPU	Display weighted fire danger rating	1.5.3
FCST	Enter forecasted weather for a specific station	3.1.1
FILE	Create, copy, delete, list, or execute user-defined files	1.7
FORM	Define display elements for DSPC command	1.5.2.1
FWXZ	Change a station fire weather zone	2.1.10
HDEF	Define type of moisture data to be entered for a station	2.1.6
HERB	Specify the herbaceous vegetation stage	2.1.5
LINK	Access ancillary routines	4.3
MODL	Specify the fuel models for a station (CTLDMP$C, SIGDMP$C, COFMOD$C and MIBKOV$C)	2.1.5
NAME	Change a station name	2.1.9
OBS	Enter regularly scheduled weather observations	2.2
OPT	Specify additional station catalog information	2.1.3
POST	Cause automatic routing of messages to other users . . .	1.9.1
SET	Control various program operations	1.4.7-.11
SIG	Originate, modify, list, or eliminate a special interest group	1.6
SPC	Enter off-station or off-hour weather observations . . .	2.2.2
STOW	Supply a FCST or ZONE command, to a temporary grouping of stations or forecast zones	3.1.4
WOOD	Specify measured woody fuel moisture	2.1.6
ZONE	Enter forecasted weather trends for a fire-weather-zone .	3.1.2
*	Producing headings on your output	1.7.3

1. GENERAL

1.1 ** PROGRAM DESCRIPTION **

dministrative and Forest Fire Information Retrieval and Management System, eferred to throughout this manual as AFFIRMS, is a user-oriented interactive omputer program designed to permit simultaneous entry of fire-weather bservations from field stations over a large network. Fire weather data may be ntered from any of a number of data terminals; then that data and the associated ire indexes may be displayed at any terminal in the network.

imple, easy-to-learn language permits entering commands to AFFIRMS. The commands all into four broad categories:

1) Commands used to enter observed and forecasted fire weather data.

2) Commands used to display weather data and/or fire danger ratings.

3) Commands used to maintain station catalogs and special interest groups.

4) Commands used to maintain user-constructed files containing either commands or plain-language text.

ield operation of AFFIRMS is intended to include:

1) Use at the Forest or District level (or similar administrative units) for the entry of observed weather data.

2) Use by fire weather forecasters for display of observed weather and entry of fire weather forecasts and narratives.

3) Use at the Forest (or similar unit) level to display fire danger indexes computed from both observed and forecasted weather, both for that unit and for any adjoining areas of interest.

4) Use at the Regional (or State) office level for monitoring fire danger over the Region (or State).

5) Use at the Interagency Fire Center at Boise for displaying fire danger indexes for any selected area of interest.

6) Use at all levels to send administrative and other messages from any user to any other user(s).

One of the most powerful features of AFFIRMS is its automatic archiving program. AFFIRMS retains only one regular observation per station. Entry of a new observation replaces the old one. An independent computer program, called the ARCHIVER, operates automatically every night at 2300 hours Mountain Standard Time. ARCHIVER inspects the files into which AFFIRMS places its regular observations. Any observations which are recognized as current will be copied and added to an archive file.

ARCHIVER retains the fire danger observation records. Periodically, it causes these records to be copied onto tape and shipped to the Fort Collins Computer Center for entry into the National Fire Weather Data Library. All of this data handling is entirely automatic. The manual keypunching of fire weather data is eliminated.

AFFIRMS permits most commands to be used in any order, any number of times. Each command is processed as it is entered, and once processed, frees AFFIRMS for new tasks. AFFIRMS is intended to be user-proof; that is, most operator errors have been anticipated and can be detected and noted without disrupting the system. Appendix A illustrates the typical user interaction with the program. Appendix B points out the most common errors that users have made in the past.

To avoid repeatedly entering such station-dependent semipermanent parameters as station elevation, agency, and time zone, a station catalog is used to store this information for program retrieval as needed. Commands are available for cataloging and uncataloging stations, as well as for specifying fuel models, slope classes, fuel conditions, and other station descriptors.

Weather data can be entered as regular-scheduled observations (OBS), off-hour or off-station special observations (SPC), and forecasts (FCST). In addition, a zone forecast feature permits entry of weather trends for an entire fire-weather forecast zone. The trends are then automatically applied to all stations in the zone and forecasts are generated for each station, based on the current weather.

Display commands are provided which permit a large selection of display options of weather and/or NFDRS indexes. Users may define special interest groups (S.I.G.) to permit groupings of stations outside such usual aggregations as county, State, and Region.

File-manipulation commands allow users to create, purge, list, and execute files. Such files are automatically made accessible to all other users, facilitating transmission of plain-language information from user to user. A posting command is included to permit automatic routing of messages to other users. Control commands are provided to permit changing standard program defaults.

1.1.1 Organization of the User's Guide

We anticipate the need to revise the User's Guide from time to time. The book is designed to allow updating instructions by issuing one or more pages rather than reprinting the entire book. Note that, instead of page numbers we have used chapter and subchapter headings for easy insertion and deletion of material. We suggest filing the Guide in a loose-leaf binder.

Chapter 1 contains instructions for all users; Chapter 2 is for the Fire Manager; Chapter 3 is for Fire Weather Forecasters, and Chapter 4 is for Regional Fire Managers. The Appendixes contain information of general interest.

1.2 ** PROGRAM COMMANDS **

Commands are entered on the keyboard of the data terminal whenever the terminal prints:

```
COMMAND:
```

This is a 'prompter' to indicate that the program is awaiting your next request. If any other response occurs after an operation, see appendix C for guidance.

After typing a command, hit the carriage-return key. This signals the computer that you are ready to have your command processed.

1.2.1 Command Format

All commands have a simple format, as described below:

1) All begin with a verb--a 3- or 4-letter abbreviation for the kind of operation you wish to perform. No spaces are allowed between the prompter and the verb.

2) Following the verb is a list of one or more operands--the numeric or alphabetic items which are the input to the command. The verb and operands must be separated from each other by a space, a comma, or a slash.

3) The number of operands varies, depending on the command used. Most commands require one or more operands; some require none at all. Many commands have a variable number of operands. These operands are also separated from each other by a space, a comma, or a slash.

Here are some examples:

```
COMMAND:CTLG 292001 1720 MST GILA 3 1 15 8
COMMAND:DATE 72/04/15
COMMAND:DSPW OBS,REG,3
COMMAND:DSPI/FCST,FOR/GILA 3
COMMAND:DEL 020209
COMMAND:POST MSG503,501,009,527
COMMAND:BYE
```

The purpose of each of these commands is discussed later in the User's Guide.

***-Note: In the first command, a space was used as a separator, in the second a slash, in the third, a comma, and in the fourth, all three were intermixed. In the fifth command, there is only one operand, while the last command has none.

1.2.2 Continuing Commands on a Second Line

Some commands, particularly OBS, SPC, and FCST can be quite long. Any command may be continued onto a second line by ending the first line with an ampersand (&) followed by a carriage return. AFFIRMS will then ask OK MORE:, and you can continue typing the command. Note that AFFIRMS attaches the text of the second line to the first line, leaving out the ampersand. If a separator (space, comma, slash) is needed, it must either precede the ampersand on the first line or be the first character typed on the second line. An example of continuation:

```
COMMAND:OBS 292001,13,1,85,78,1,15,NW,5,3,90,&
OK MORE:72,90,30,0,0,1,23
```

1.2.3 Entering Missing Data

In certain situations, you may need to indicate missing data for one or more operands. This may be accomplished by using the single letter M as an operand.

Only the ARCH, FCST, OBS, OPT, SPC, and ZONE commands permit missing-data entries, and only in certain operands. In an OBS command, you would indicate a missing maximum temperature this way:

```
COMMAND:OBS 292001,15,1,69,65,1,30,NE,3,10,M,56,85,34,0,0,1,24
```

1.2.4 STACKING Multiple Commands in One Entry

More than one command may be entered at one time; either on a single command line, or in a two-line continued format, as described in 1.2.2.

Multiple commands must be separated from each other by the exclamation point (!). After a multiple-command line has been typed in (followed by the carriage-return), AFFIRMS analyzes the first command on the line and executes it. Then, if an exclamation point is found, the second command is processed, the third, and so on, just as if the commands had been typed in separately.

For example:

```
COMMAND:SET DAYS 1 HEAD OFF! DSPW OBS SIG 012
```

A long two-line multiple command series could also be entered:

```
COMMAND:DSPW OBS SIG 154 ! SET HEAD OFF ! DSPW OBS&
OK MORE:CNTY 0456! SET HEAD ON ! DSPX OBS SIG 154
```

Note: Blanks (spaces) can be put in before and/or after the exclamation point.

Note that no STACKED commands may follow any FILE commands on the same line.

Use of multiple-command lines noticeably speeds up processing of commands.

If a syntactic error is encountered in a multiple-command line, a message will advise that the text following the erroneous command has been ignored.

1.2.5 Requesting AFFIRMS Operational Schedule--SCHED$L

Periodically, the hours that AFFIRMS is available change as G.E. schedules regular maintenance or changes hardware. These changes are announced by G.E. with a message like:

```
HH
U#=MAN68709,GEORGE,STRAUB
PLEASE RUN SCHED*** FOR WEEKEND SCHEDULE CHANGES.
NFDR AFFIRMS (RSH:118/25/ 4/ 5)
```

The AFFIRMS user does not have the capability to run SCHED***. Therefore, the AFFIRMS staff does this for you and places the changes in a permanent file named SCHED$L. To receive a copy of the schedule, follow the illustration below.

```
COMMAND:FILE LIST SCHED$L
AFFIRMS NETWORK SERVICE AVAILABLE 24 HOURS EXCEPT:
OFF SAT. 14:45 TO 15:00 MDT
OFF SAT. 22:00 TO SUN. 08:00 MDT
OFF MON. 21:45 to MON. 2200 MDT
OFF TUE. 04:45 TO TUE. 05:00 MDT
```

*** Note: This is an illustration only and may be very different from the actual schedule on any given day.

1.2.6 Getting Tutorial Assistance

Tutorial information about AFFIRMS commands is available by entering:

```
COMMAND:FILE LIST TUTOR$D
```

AFFIRMS will respond by printing a summary of command forms and assistance phone numbers. When the command in question has been listed, you can prevent any further listing of these tutorials by hitting the Break-key.

1.2.7 Requesting Past NFDR-AFFIRMS Announcements--BLURBS$L

Both the National Fire Danger Rating System and AFFIRMS are dynamic systems with technical and administrative changes occurring from time to time. If you are a new user, or an old one returning after an absence of several months, check the file named BLURBS$L to bring yourself up to date. An example of this request:

```
COMMAND:FILE LIST BLURBS$L

ALL USERS:

PLEASE REMEMBER THAT IF YOU EVER GET AFFIRMS ERROR
MESSAGES WHICH HAVE THE LETTER 'R' AS THE SIXTH
CHARACTER OF THE MESSAGE NUMBER, YOU SHOULD CONTACT
BOISE A.S.A.P.

FOR EXAMPLE...

    ........... THIS IS THE LETTER TO WATCH FOR:

    FIL03R SEQ. FILE READ-ERROR,  CODE:  107
```

```
THE 'R' STANDS FOR 'REFERRAL'.  THE USUAL SUFFIX
IS 'A' FOR ACTION OR 'I' FOR INFORMATION.

ALL  AFFIRMS USERS:

G.E. WILL BE MOVING US FROM SYSTEM 'B' TO SYSTEM 'L'
LATE THIS SATURDAY (NOV. 2) EVENING.

ALL THIS MEANS IS THAT YOUR USER NUMBER'S FIRST LETTER
WILL CHANGE FROM 'B' TO 'L'.  EXAMPLE:  BAN68711 BECOMES
LAN68711.

PLEASE REPORT ANY STRANGE GOINGS-ON AFTER THE CHANGE-
OVER HAS BEEN MADE.

---

COMMAND:
```

***-Note: In this example, BLURBS$L contained two announcements. You were returned to the COMMAND point when the list was complete. Since the list is typically much longer, read along with the printer and terminate the listing by hitting the Break-key when you begin to see familiar announcements.

.2.8 Directory of AFFIRMS Users -- USRLST$L

A directory of user numbers, names, four-letter unit abbreviations and airport codes is available from an AFFIRMS file. User numbers are needed for the POST command explained in Section 1.8.1. Four-letter abbreviations can be used in the display commands specifying a particular unit as explained in Section 1.5.1. Three-letter airport codes of National Weather Service offices are used to obtain fire weather forecast narratives as explained in Sections 2.3 and 3.1.6. To receive this directory, type:

```
COMMAND:FILE LIST USRLST$L
```

This list of users is several pages long and changes infrequently. Requesting it once or twice a season should be sufficient. Some Central Offices have saved money by sending copies of their list to users in their local area.

1.3 ** TROUBLE SHOOTING **

1.3.1 Error Detection

AFFIRMS can detect many common errors, including 1) bad syntax, 2) impossible or inconsistent data-values, and 3) required data entered as missing. In most cases, the specific location of the error in the command-line will be indicated with an up-arrow (↑). For example:

```
COMMAND:MODL 292001,5,A2P,1418,B3P,17
ERROR AT ..............................↑
CTL04A IMPROPER LENGTH
COMMAND:
```

The program indicates the operand in which the error was detected and a brief note is made of the kind of error found. The error code, CTL04A, may be looked up in appendix C of this guide, where a more detailed explanation is provided. In this case, AFFIRMS detected that the manning index percentiles for a MODL command had the wrong number of digits (four, five, or six were expected but only two were found).

1.3.2 Error Correction

The AFFIRMS program allows two methods of correcting errors in a line of input before the carriage return key is depressed. The operator can delete individual characters in a line or the entire line if needed. Different brands of computer terminals have different symbols for these functions. Th back arrow is the most common character-delete symbol and the "control X" th most common way of deleting a complete line. Instruction manuals, sales respresentatives, or the office listed at the front of this publication can help you with specific questions. The ASCII binary code for the G.E. backspace is 1011111, while the control X is 0011000. Examples of these functions follow:

```
COMMAND:DSPQ←I OBS  LIST 041010 040101
COMMAND:DSPI OBS LIST 041010 040101 DELETED
DSPI OBS LIST 041010 040101
```

In the first example, the back arrow caused the computer to back up one space allowing the letter I to be typed in to replace the erroneous letter O. In the second example, the error was not recognized until the entire line was completed. It is not practical to use multiple back spaces to clear the entire line. A break-key or carriage return would cost about 15¢ because AFFIRMS would respond with an error message. The line was deleted by pressing the control key and the "X" at the same time. "DELETED" is printed and the carriage returns to the left hand margin. Since the computer did not see the deleted material, a COMMAND: prompter was not reprinted. The corrected input line was typed starting at that point. See Section 1.4.4 for use of the break-key.

If you made an error in the retyped line, the position of the up-arrow (↑) will not accurately indicate the defective item in the command line. This is due to the lack of the word COMMAND: off-setting the input line eight spaces. (Line-delete and character delete are performed by 'front-end' equipment, not by the computer itself.)

1.3.3 System Failures

Because AFFIRMS is a program which operates on a multipurpose commercial computer network, it is possible for certain types of system failures to directly affect the user. Under some conditions, you may receive error messages which do not originate in AFFIRMS, but rather in the computer operating system. Examples might be:

1. SERVICE TEMPORARILY INTERRUPTED
2. SYSTEM UNAVAILABLE ENTER ALTERNATE U#
3. Phone rings -- but no answer, or line is constantly busy
4. ::SOME MESSAGE::

```
::SOME MESSAGE::
LINE CALLING ROUTINE
999  ::SOMENAME::
999  ::SOMENAME::
READY
```

***-Note: In the situation listed above, the user would contact G.E. for the first three problems. When calling G.E., identify yourself and remember that G.E. people know nothing about the internal programing of AFFIRMS. They can only help in such situations as those in examples 2 and 3; and persistent repeats of example 1. Probable actions on the above examples would be:

Ex. 1: Wait a few minutes and try again.

Ex. 2: YOU: "Can you tell me how soon system 'M' will be operating?" (M is the first letter of your user number. Note: This letter will change, depending upon G.E. schedules.)

GE: "Probably within 15 minutes." [Down times are rarely very long.]

Ex. 3: YOU: "I'd like to report that the port in Rialto, California is ring-no-answer. The access number is area code 714, 875-8751. Is there another number in that area?"

GE: "Try 825-5781 in Colton."

The toll-free G.E. user assistance number is 800-638-8730.

The fourth example should be referred to the AFFIRMS staff at the telephone numbers listed on the program heading. Please send your printed output or a machine copy of it to us. These 'tracebacks' are invaluable in finding and correcting program bugs. A vague verbal description like 'something went wrong' is not much help in a program of this size. The entries of RUN (to go back to AFFIRMS); or BYE (to sign off) are correct responses to READY or WHAT. If these responses fail, hang-up and reaccess AFFIRMS.

5. Extremely high session costs or other very unusual occurrences should be reported to the AFFIRMS staff. SAVE THE PRINTED OUTPUT.

6. VALIDATION FAILURE, PLEASE CONTACT YOUR T/S REPRESENTATIVE. This message is usually the result of not following the sign-on format exactly. Check your entry, including the punctuation, and call the AFFIRMS staff if everything seems in order. Sign-on MUST follow an EXACT format.

7. The error message code coming from AFFIRMS end in one of three possible letters: "A," "I," and "R." All "R" messages should be reported to the AFFIRMS staff. See appendix C for explanation of the error message.

1.4 **TERMINAL OPERATIONS **

1.4.1 Accessing AFFIRMS

The AFFIRMS program can be reached by a large number of computer terminals, with varying keyboard layouts and hardware switches. Rather than producing instructions for all these possibilities, a few common, but important, switches are discussed. Note that not even these necessarily exist on your machine. (Hardware questions not addressed here can be referred to the staff at the address on the frontispiece of this manual.)

Switch	Position
Duplex	HALF
Mode	ON LINE
Speed	30 (however, 15 and 10 will work)
Parity	EVEN

***-Note: Given a choice, always select 30 characters per second as the sending speed since faster printing reduces the time spent on the system and, therefore, reduces costs.

An AFFIRMS session begins by dialing the local telephone number of the computer network on which AFFIRMS is implemented. When the computer "answers" and sends back a high-pitched tone, the handset of the telephone i placed in the audiocoupler on your terminal. The audiocoupler has two rubbe cups which fit a standard phone handset. As soon as your terminal detects the presence of the carrier signal, it will send back an acknowledging signa and will light up an indicator on its control panel. Usually, this light is marked as Carrier Detect, Ready-to-Send, or On-Line. No light at this point usually indicates that the telephone handset is in backwards.

Within the first 5 seconds after the indicator lights, you must send the character H several times. The device which connects the telephone line to the computer will analyze the way in which your terminal sent the H and adjust itself to the proper speed and mode of transmission. If no response is made by the computer to the H's, check to insure that your terminal is in the "On-Line" mode.

The computer network will then request the log-on sequence containing a user-number, password, and user-name. The protocol for this sign-on is very specific and must be followed exactly since you are not yet dealing with AFFIRMS but with the operating system itself. AFFIRMS will tell you what mistakes you have made, but since the computer network does not want anyone to use its services who is not authorized to do so, it is very intolerant of errors during the log-on procedures.

You type in the log-on sequence and follow it with carriage return. Depressing this key always signals the computer to accept a line of information. The computer will never start to process what has been typed until the carriage return key is hit.

Your user-number is set up so that is has only one possible function--it can access the AFFIRMS program--nothing else! As soon as the user-number is recognized, the AFFIRMS program will be loaded and made ready for your command. An example follows:

```
HH 1/

U#=2/MAN 68707,MARANA,DCP 3/  (CR) 4/

                           5/
INCORRECT FORMAT, REENTER U#MAN68707,MARANA,DCP 6/ (CR) 7/
```

1/ User typed in HH

2/ Computer has replied U#= indicating "User number please".

3/ User has used an incorrect format, note the space between MAN and 68707.

4/ The carriage return key was depressed signalling the entry completed.

5/ Computer has rejected the entry and asked for another try. You have three tries to enter a correct user number.

6/ User has correctly entered his user number, password, and user name. Typing started immediately following the last symbol from the computer.

7/ Carriage return key must always be depressed at the end of each line of information to enter the information into the computer.

1.4.1.1 Messages Received at the Start of an AFFIRMS Session

After the computer has accepted the user number, several types of messages may be received. These messages may come from the computer network or the AFFIRMS program.

Messages from the computer network precede the "NFDR" banner and should be ignored if they direct action on your part. The AFFIRMS staff will carry ou any required tasks for all users. An example of a message that should be ignored is:

```
BACKGROUND USERS PLEASE RUN SCHED**FOR UPDATED SCHEDULE
CHANGES.
```

Now AFFIRMS will print a message containing the version of the program and the communications equipment identifiers; for example, NFDR '78 AFFIRMS (118/25/4/5). This banner indicates you are using the AFFIRMS program. The information within the parenthesis contains the program version/port number/the remote concentrator/local concentrator. These last three numbers will be required by G.E. to track down communications problems that are reported.

At this point, two kinds of messages can be received: 1) messages from the AFFIRMS program staff; 2) messages originating from other users and sent to you by the POST command. An example of these messages follows:

```
FOR AID CALL  (208) 384-9455 (Com) or FTS 554-9458

EXC061 MSG  /DEEM711 / FROM USER-NO. 711 DATED 780809

DEEMING:  TRIED TO REACH YOUR OFFICE THIS PM BUT COULDN'T
GET THROUGH YOU CAN REACH ME AT THE 5 R.O. (JACK CARTER'S
OFFICE) BETWEEN 10 AM and 3 PM ON THE  20TH (TUESDAY)
........HELFMAN
- - -
```

***Note that three dashes (---) signal the end of each message.

Finally, AFFIRMS issues a COMMAND: prompter to tell you it is ready for your first request. An example of the complete sign-on procedure follows:

```
HH

U#=MAN68519,WHIZBANG,SMITH

NFDR '78 AFFIRMS (328/28/8/3)

FOR ASSISTANCE, CALL FTS 554-9458 OR COM (208) 384-9455

EXC06I MSG 'EXAMP709' FROM USER-NO. 709 DATED 7903/05.

HI THERE, I SEE THAT YOU HAVE SUCCESSFULLY MADE YOUR FIRST CONTACT WITH
THE AFFFIRMS PROGRAM....BOB STRAUB ---

COMMAND:
```

1.4.2 Obtaining A User Number and Password

Contact the National Fire Danger Rating, CFP, S&PF Liaison Office at BIFC, 3905 Vista Avenue, Boise, ID 83705, or FTS: 554-9455, COM. (208) 384-9455.

1.4.3 Terminating an AFFIRMS Session--the BYE Command

The BYE command is used to exit from AFFIRMS and disconnect your terminal. Sessions should always be ended with BYE as this assures that all system housekeeping has been properly completed. Ending the session by simply hanging up the telephone should be avoided whenever possible.

The command can take two forms. The comments after the examples below indicate what each form does:

BYE	The session ends and the terminal shuts down.
BYE NEW	Ends the present session and permits the user to sign on with another user number, password, and ID (combination) without redialing the telephone.

Before the computer disconnects, an estimate of the cost of the session will be printed (this figure reflects government discounts which may not apply to nongovernment users).

Terminating an AFFIRMS session:

```
COMMAND:BYE
(TSP) COST: $   6.04
00023.07   CRU    0000.22 TCH   0003.38   KC

OFF AT 10:33MDT   08/19/78
```

***-Note: CRU - Computer Resource Units - physical equipment used
TCH - Connect time in decimals of an hour
KC - Thousands of characters sent and received.

1.4.4 Escape Provisions (Use of the Breakkey)

If you enter a command and then wish to abort it, hit the breakkey once. You will be returned to the COMMAND: point.

The breakkey may be hit at any time to interrupt the program in any task. It is important to realize that the task is actually abandoned. If you enter an OBS command and then hit "Break" before AFFIRMS asks for the next command, the observation will not be stored and cannot be retrieved. See Sec. 1.3.2 for use of the back space and delete functions.

Whenever the breakkey is hit:

1) The date is set back to today even if a DATE command preceded has been executed.
(See Section 1.4.6).
2) The program goes back to terminal mode even if it was processing in file mode (see Section 1.7.2).

1.4.5 The Control Shift

As you have come to expect from using typewriters, computer terminals have a shift key allowing the change from lower to upper case letters and numbers. The AFFIRMS program is case blind--that is, it makes no difference if it receives a "B" or a "b", the same action results. It is usually most convenient to set the keyboard so that shifting is not required to send the numerals. By setting the character switch, it is possible to get both capital letters (easy to read) and numbers without shifting back and forth.

Unlike a typewriter, terminals have a second shift. It is called the CONTROL shift and will usually be located above the lefthand regular shift key. By holding this key down and typing with the other hand, a series of nonprinting control signals can be sent. These control signals are identified by the strange two- and three-letter abbreviations on some of the otherwise normal keys.

AFFIRMS only uses one of these control functions, that is the control CAN or control "X." Hitting this key allows the line you are presently typing to be destroyed and retyped without returning to the COMMAND prompter. This technique is particularly useful while constructing files since it permits limited repairs without having to start the entire file over.

***-NOTE: IF READING THROUGH FOR THE FIRST TIME, THE REMAINDER OF SECTION 1.4 SHOULD BE SKIPPED UNTIL SECTION 1.5 HAS BEEN STUDIED.

1.4.6 Changing The System Date--the DATE Command

The DATE command permits today's date to be overridden during execution of some date-dependent commands.

The DATE command requires three operands:

Year;	A two-digit number (for example, 78 for 1978)
Month;	A two-digit number (for example, 08 for August)
Day;	A two-digit number (for example, 03 for the third)

As soon as the break-key is hit, the date automatically reverts to today. An example of a DATE command:

```
COMMAND:DATE 78,03,27
EXC04I DATE OVERRIDDEN 78/03/27
```

If an OBS command were now entered, the data would be considered by AFFIRMS to apply to March 27, 1978, rather than the current date.

The DATE command is of particular interest to fire-weather forecasters. They frequently want to update their forecasts in the morning utilizing yesterday afternoon's observations. By entering a DATE command which specifies yesterday's date, followed by a ZONE command, the trends specified will be applied to yesterday's observations and forecasts will be generated with today's date. (If the DATE command were not used, AFFIRMS would look for observations dated today which would not be available in the morning.)

Only the following commands are legal while a DATE command is in effect:

> OBS, FCST, ZONE, HERB, WOOD, DATE, DSPW, DSPI, DSPX,
> DSPM, DSPS, ARCH, FORM, DSPC, STOW, SET, LINK, DSPU,
> FILE, and BYE.

1.4.7.1 Displaying Stale Data--The SET DAYS Command

Sometimes you may wish to display stale data from stations which have not currently reported; that is, observations not dated today or forecasts not dated tomorrow. The SET DAYS command allows you to do this. Recall that AFFIRMS only holds the most current data in accessible storage. Today's OBS overwrites yesterday's OBS.

The SET DAYS command has the form:

```
SET DAYS nn
```

Where nn indicates how many days you want the computer to look back for stal data in subsequent displays. You may use any number from 0 to 31 or -1. A value of 2 will cause data for today or up to 2 days earlier to be displayed A value of zero will cancel previous SET DAYS commands.

To limit displays to tomorrow's forecast only, a value of -1 can be used. I the DSPU command is used and tomorrow's forecast DSPU is desired rather than the forecast for today, the SET DAYS -1 must be used.

***-Note: AFFIRMS shows only the latest data entered. SET DAYS simply allows you to ignore or accept stale data as you wish.

1.4.7.2 Suppressing Display Headings--The SET HEAD Command

The SET HEAD command allows you to control whether headings will appear abov data listed with any of the display commands. For example, if you were doin several DSPW displays, you could allow the heading on the first one and turn off the headings on the subsequent ones. This saves both time and computer costs; it takes the savings from three or more headings, however, to offset the cost of proccessing this command. The SET HEAD command takes two forms

```
SET HEAD OFF - Headings will not be printed on subsequent displays.
SET HEAD ON  - Headings will be restored on subsequent displays.
```

1.4.7.3 Displays with Station Names--The SET NAME Command

The AFFIRMS program is structured to begin each line of display with the six-digit station number. If the user's operation is better served by a display identified with the station name, this number can be replaced with a six-letter abbreviation of the name. This command has the form:

SET NAME ON	Each display line starts with the name
SET NAME OFF	Each display line starts with the number

If a station has not been named (either when initially cataloged or subsequently with the NAME command), then the station number will appear regardless of the SET NAME command.

1.4.7.4 Requesting Statistics on DSPW OBS Display--The SET MEDIAN and SET MEAN Commands

A pair of SET commands exists to allow the user to get both the median and/or the mean values of the weather elements displayed with the DSPW OBS command. They have the form:

SET MEDIAN ON	Median values follow the display
SET MEAN ON	Mean values follow the display

Both of these commands are terminated by the command SET MEDIAN (or MEAN) OFF or when the session ends.

If the SET commands precede a DSPW OBS in which the data from at least three but no more than 20, stations is retrieved, the median or mean values of dry bulb temperature, relative humidity, windspeed, maximum and minimum temperatures, maximum and minimum relative humidities and precipitation duration are printed out at the bottom of the display.

The median value is defined as "that value above and below which an equal number of observations will be found when all of the observations are arranged in order of magnitude." The mean is "the average numerical value."

1.4.7.5 Mixing SET Commands

To save typing required of both the system and the user, all SET commands can be combined on one line. You must retain the paired structure. For example:

```
SET NAME ON,DAYS 5,HEAD OFF,MEAN ON
```

This example is perfectly legal and is interpreted by the computer as:

```
SET NAME ON
SET DAYS 5
SET HEAD OFF
SET MEAN ON
```

1.4.7.6 Forecasting Dewpoint Temperature--The SET DWPT Command

Many forecasters think of air mass moisture in terms of dewpoint temperature. To save the time required to convert dewpoint to relative humidity (RH), AFFIRMS can be directed to accept dewpoint in the FCST and ZONE commands where RH would normally be expected. This command has the form: SET DWPT ON.

From the receipt of this command and until SET DWPT OFF or the Sign Off is encountered, the moisture input to FCST and ZONE commands will be automatically converted to RH from dewpoint temperature.

In the case of the ZONE command, the dry bulb temperature is trended, the C time RH converted to dewpoint and also trended. These two trended values a then used to determine the forecast RH.

Note: The Max and Min RH values are not affected by this SET command.

1.4.7.7 Changing BREAK Control Key--the SET BREAK Command

The break key is used in several important ways in the program, such as closing files, turning back the date, and terminating an erroneous command. The BREAK is not a character in the normal sense; therefore, it cannot be put on either magnetic or paper tape. An alternate key can be selected to perform these BREAK functions if tape operations require it. The form of the command is: SET BREAK #.

Note: In this example, a number symbol was used. BE CAREFUL! Any character will work and most characters are already used for something else. Never set the BREAK key to a letter, number, blank, comma, period, exclamation, ampersand, semicolon, $, or slash. The best choice left is #.

Once set to something else, the BREAK function cannot be set back to a break key, since this key does not send a normal character. It does return to normal with the Sign Off.

1.4.7.8 Limiting the Station Output--the SET LINES Command

The program permits a user to catalog as many as four combinations of model-slope-herbaceous type per station. Whenever a display is requested that contains information that varies by these combinations, as many lines of output as there are combinations will be printed. Often another user wishes to display data from this station, but does not want to see all of the combinations. The command has the form:

```
SET LINES (number from 1 to 4)
```

Since this command is often used by headquarters units to reduce the total volume they receive, the cataloging unit should make the first combination the most important one for that station since that may be the only one monitored.

1.4.7.9 Initial 1000HR Moisture - The SET THOU Command

AFFIRMS begins each observational season by setting the 1000HR fuel moisture for a station to a default value based on climate class. These defaults are 15, 20, 25, or 30 corresponding to climate classes 1, 2, 3, or 4. The need for initialization is determined by whether or not a 50-day break occurs in the observations.

Often the manager has a better value available than these defaults, based on nearby stations that have operated throughout the season, or from actual measurement of the heavy fuels. This better value is entered with the SET THOU command. This command must be entered in the same session as the first OBS of the season and before the OBS itself is entered. The form is:

```
SET THOU (value from 2.0 to 200.0)
```

This SET will affect any station that has its first OBS entered after the SE and in the same session as the SET. Any station without a 50-day observational gap will not be affected. If the 1000 hour fuel moisture is error, see Section 4.4 for a method of forcing it to another value.

1.4.7.10 Magnetic and Paper Tape Timing--The SET TAPE Command

Many users of AFFIRMS prepare magnetic or paper tapes off-line for later entry into the system. This process permits editing the input for errors before connecting to the computer. When large bodies of input data must be entered this technique is worthwhile because of the savings in connect time and increased accuracy of the data.

The devices that read these prepared tapes into AFFIRMS use a different timing sequence than do normal keyboard operations. To make the computer aware that this other timing is about to occur, send a SET TAPE ON command just before the FILE MAKE command (see Section 1.7.1). The command has the form:

```
SET TAPE ON
```

**Note: This is the one SET command that automatically cancels itself when the break key is hit to close the file just created. If two files are to be created, then the SET Command must be repeated.

1.4.7.11 Printing Back Erroneous Commands--The SET ECHO Command

This feature causes AFFIRMS to print a copy of any command it has received that has generated an "ERROR AT" message. Unless the user enters the 'ON' half of this command the feature is not active. The command has the form:

```
SET ECHO ON
```

The copy printed is the command text as seen by the computer. Thus, the feature is useful in detecting noisy phone lines which sometimes garble your commands before the computer ever sees them.

.4.7.12 Screening Display Output by Manning or Adjective Class- The SET MC Command and SET AC Commands

(See Section 4.1)

.4.7.13 Controlling the Minimum Wait Time--The SET WAIT Command

Several terminals (techtronics) and minicomputers require the ability to delay AFFIRMS responses. The SET WAIT command can define wait times of 1 to 30 seconds. An ESC ETB sequence is used. The form of the command is:

```
SET WAIT (1 to 30)
```

1.5 ** DISPLAYING WEATHER AND FIRE DANGER INFORMATION **

The commands used to display weather and fire danger ratings have the form:

```
Verb type,Scope,nnnnnn,mmmmmm
```

**The SET commands influence the content of displays. See Sections 1.4.7.1 through 1.4.7.13.

1.5.1 Displaying Station Weather and Fire Danger Information--the DSPC, DSPI, DSPM, DSPS, DSPW, and, DSPX Commands

The command Verb determines if weather or computer fire indexes are displayed. Five Verbs are used:

DSPC	The C indicates a Custom display (Custom).
DSPI	The I indicates a fire danger rating display (Indexes).
DSPM	The M indicates a managers F.D.R. display (Manager).
DSPS	The S indicates the shortest F.D.R. display (Short).
DSPW	The W indicates a weather display (Weather).
DSPX	The X indicates an abbreviated F.D.R. display.

Type specifies whether observed or forecast data is to be displayed. Three operands are used:

OBS	Weather or fire danger data derived from the regular, fire weather observations.
SPC	Weather or fire danger data derived from off-time or off-site weather observations.
FCST	Predicted weather or fire danger ratings.

The second operand, Scope, specifies what geographical or political criteria are to be used in selecting the data to be displayed. Only those stations which meet your criteria will appear in the output. Nine operands are available to specify the scope of the display.

REG	U.S. Forest Service Region, or Regions
STAT	State
CNTY	County
ZONE	Fire Weather Zone
SIG	Special-Interest-Group (S.I.G.)
ID	Single station or range of stations
LIST	List of specific station numbers
UNIT	National Forest or administrative unit

The third and fourth operands (nnn... and mmm...) are used to indicate numeric value of the scope operand specified.

You may use any combination of Verb, Type, and Scope to create any selection criteria you wish. Below are some examples of the more commonly used combinations:

DSPW OBS,ID,020503	(Display OBS weather for station no. 020503 only.)
DSPI SPC,ID,201009,495689	(Display SPC indices for all stations with numbers between 201009 and 495689.)
DSPW OBS, ZONE 303 3	(Display OBS weather for all stations within fire weather zone 303 in Region 3.) Note that both the zone number and Forest Service Region number must be entered.

DSPM,FCST UNIT,KOOT,1	(Display forecast values for Kootenai NF, R-1. Four-letter abbreviations for units and forests are found in the USRLST$L, Section 1.2.7. Note that Forest Service Region number must be entered.) This is the most expensive way of getting a display: avoid it.
DSPI FCST,STAT,29	(Display FCST indexes for stations in state number 29.)
DSPM OBS,CNTY,2920	(Display OBS indexes for station located in county 20 of state 29.)
DSPW FCST,REG 3,4,5	(Display FCST weather for stations located in Regions 3, 4, and 5.)
DSPX OBS,SIG 006	(Abbreviated display OBS indexes for those stations previously placed in S.I.G. 006.)
DSPS OBS,LIST,020202,045691,292001,045302,045228	(Display OBS manning for the listed stations - up to 18 numbers can be entered.)

***Note: Each fire weather station has been assigned a six-digit identifier code by the National Weather Service. The first two digits indicate the State; the second pair, the county; and the third pair, the specific station within that county.

1.5.2 Examples of Display Headings/Formats

There are six standard display format. Examples of the displays are:

```
COMMAND:DSPW OBS ID 045691

----------------------05/11/78--OBS---17:47GMT------------------------
STAT'N HR DY W DBT DPT  RH Y M DIR WS 10 TMX TMN HMX HMN PD PPAMT UNKO
045691 13 10 2  75  52  45 3 2  NE  9 16  79  56  75  35  0  0.00 FAKE
```

```
COMMAND:DSPW FCST ID 045691

----------------------05/11/78--FCST--17:48GMT----------------------
STAT'N DY HR W DBT DPT  RH AL TL DIR WS 10 TMX TMN HMX HMN P1 P2
045691 11 13 0  85  62  46  1  1  NE 12 13  90  57  57  26  0  0
```

```
COMMAND:DSPI OBS ID 045691

----------------------05/11/78--OBS---17:48GMT--------------------------
STAT'N MSGC DY WS WDY HRB 1H 10 HU TH IC LR LO MR MO  SC  EC  BI FL MC R 045691
A3P3 10    9   0 164  6 16 17 24  9 13  3 35  3  10   0   5  6 2- L
```

```
COMMAND:DSPX OBS ID 045691

----------------------05/11/78--OBS---17:49GMT-----------
STAT'N MSGC DY HR TH IC LR LO MR MO  SC  EC  BI FL MC R
045691 A3P3 10 13 24  9 13  3 35  3  10   0   5  6 2- L
```

```
COMMAND:DSPM OBS ID 045691

---------------------05/11/78--OBS---17:49GMT---------------------
STAT'N MSGC DY DBT DPT  RH WS PPAMT PD 1H 10 IC  SC  EC  BI FL MC R
045691 A3P3 10  75  52  45  9  0.00  0  6 16  9  19   0   5  6 2- L

COMMAND:DSPS OBS ID 045691
--05/11/78--OBS---17:49GMT--
STAT'N MSGC DY PPAMT PD MC R
045691 A3P3 10  0.00  0 2- L
```

1.5.2.1 Setting Up Custom Displays - The DSPC and FORM Commands

DSPC provides the user with a completely flexible way of producing displays. The DSPC command works exactly the same way as such display commands as DSPW and DSPI. It permits the *User* to determine precisely which data items will appear in the display line and in what order they will be printed. The "FORM" command is used to make this specification.

The syntax for the FORM Command is:

```
COMMAND:FORM LL,MM,NN,....
```

Where the LL,MM,NN,... are up to 20, one- or two-digit item-numbers selected from Table 1.5.22. Item numbers range from 1 to 47.

Once a FORM command is entered (either from your terminal's keyboard or from a command file), it remains in effect until your either sign-off or enter another FORM command.

The table of item numbers is shown in alphabetical order by the 'HEADING' which each generates in any display - including the standard displays shown in 1.5.2.

For example, if one wanted the following items to appear in the display line:

```
STAT'N DY MSGC DBT PPAMT UNKO  LR SC FL MC
```

Then one would use this FORM Command:

```
COMMAND:FORM 1,4,41,5,15,22,32,36,39,40
```

Note that the order you use to enter the 'ITEM-NUMBERS' is the order in which the custom display will print those items.

You should usually include item number 1 (STATION NUMBER) in any FORM command. Item number 41 (MODEL SPECIFIER 'MSGC') should be included in any FORM command which includes an item number of 32 or higher (that is, model-dependent items).

It is also permissible to have the same item number appear twice. This is handy for having the station name appear at both ends of the display line.

Once you have entered the FORM command, you can have any number of DSPC commands after it, and they can be intermixed with any of the normal displays.

If you want to change the arrangement of the custom displays later in the session, you simply enter another FORM command with the new specifications.

For convenience, you should determine what kind of customized displays you need in your work. You can then build FORM and a DSPC commands in a command file. You can then get your customized display by just entering a FILE READ command (see Sections 1.7.1 and 1.7.3).

These commands will be very useful when you find that the standard displays give you too much or too little information.

1.5.2.2 ITEM-NUMBERS For Use In The FORM Command

DATA DESCRIPTION	HEADING SHOWN	ITEM NUMBER
AFTERNOON L.A.L. (FCST ONLY)	AL	25
ADJECTIVE RATING *	R	42
BURNING INDEX	BI	38
DATE (YYMMDD)	DATE	48
DAY (DD)	DY	4
DEWPOINT (COMPUTED, DEG. F)	DPT	20
DIRECTION (WIND)	DIR	9
DRY-BULB TEMPERATURE (DEG. F)	DBT	5
ENERGY RELEASE COMPONENT	EC	37
FIRE LOAD INDEX	FL	39
FREEZE COUNTER	FZ	31
FUEL MODEL-SLOPE-GRASS TYPE-CLIMATE CLASS	MSGC	41
HERBACEOUS FUEL MOISTURE	HRB	43
HERBACEOUS STAGE CODE (NOT THE SAME AS CATALOG HERB COMMAND INPUT)	V	46
HOUR OF OBSERVATION (OR FORECAST)	HR	3
100-HOUR-TIMELAG FUEL MOISTURE	HU	28
IGNITION COMPONENT	IC	33
LIGHTNING OCCURRENCE INDEX	LO	34
LIGHTING RISK	LR	32
MAN-CAUSED OCCURRENCE INDEX	MO	35
MAN-CAUSED RISK (TODAY'S)	MR	21
MAN-CAUSED RISK (PREDICTED - OBS ONLY)	PR	19
MANNING CLASS **	MC	40
MAXIMUM RELATIVE HUMIDITY (PCT)	HMX	13
MAXIMUM TEMPERATURE (DEG. F)	TMX	11
MINIMUM RELATIVE HUMIDITY (PCT)	HMN	14
MINIMUM TEMPERATURE (DEG. F)	TMN	12
MORNING L.A.L. (OBS ONLY)	ML	18
1-HOUR-TIMELAG FUEL MOISTURE	1H	27
OPTION LEVEL (COMPUTED)	O	30

DATA DESCRIPTION	HEADING SHOWN	ITEM NUMBER
PREDICTOR VALUE FOR 1000-HR	X1000	45
PRECIP. AMOUNT	PPAMT	15
PRECIP. DURATION (1ST PERIOD, FCST)	P1	23
PRECIP. DURATION (2ND PERIOD, FCST)	P2	24
PRECIP. DURATION (TOTAL, OBS)	PD	16
RELATIVE HUMIDITY (PCT)	RH	6
SPREAD COMPONENT	SC	36
STATE OF WEATHER	W	7
STATION NAME (AFFECTED BY SET NAME ON)	STAT'N	1
STATION NUMBER	STAT'N	47
10-HOUR-TIMELAG (STICK) FUEL MOISTURE	10	8
1000-HOUR-TIMELAG FUEL MOISTURE	TH	29
TOMORROW'S L.A.L. (FCST ONLY)	TL	26
UNIT NAME	UNIT	2
'UNKO'FIELD	UNKO	22
WINDSPEED (MPH)	WS	10
WOODY FUEL MOISTURE	WDY	44
YESTERDAY'S L.A.L. (OBS ONLY)	YL	17

*See Appendix D

**See Appendix E

1.5.3 Comparative Efficiency of Display Options

Users should be aware of the varying costs of the display options. The following list is in order of increasing costs (decreasing efficiency). The display scopes grouped in parantheses are equally efficient:

(REG,ZONE,STAT,CNTY)(ID,LIST)SIG,(FOR,UNIT)

UNIT scope should be avoided when possible since it results in the highest cost to the user. This does not mean that you should never use it; rather, it means that it should not be adopted for day-to-day routine operations. The SIG scope joins the next best cost group if it contains five or more stations.

1.5.4 Displaying Weighted Average Fire Danger for a Protection Unit -- the DSPU Command

The DSPU command allows the AFFIRMS user the flexibility to produce a display of the weighted fire danger information associated with up to nine individual stations. This command provides a mechanism for the user to consider the relative importance of all the available stations in the area of interest and to produce a single integrated display of the fire danger on that area. See appendix F for details on the DSPU weighting method.

The command has the form:

```
DSPU TYPE,REGION,STA-NO-MODEL-SLOPE,WEIGHTING FACTOR
```

In which:

- Type; OBS,SPC or FCST (See 1.5.1)
- Region; A one- or two-digit USFS Region number in which all the stations which follow are found.
- Sta-No-Model-Slope; eight characters: six for station number, one for fuel model, one for slope classs. A maximum of nine stations are allowed.
- Weight; A one- or two-digit number indicating the percent of the final rating that this station is to contribute.

NOTE that the herbaceous indicator, annual or perennial, is not given. If a station has the same model and slope associated with both an annual and a perennial combination the program will use whichever one appears first in the MODL command.

For example:

```
COMMAND:DSPU OBS 5,045408G2 20,045409I3 25,045413A1 15, &
OK MORE:045110B3 30,045414B3 10
```

When preparing this command, check to insure that the sum of all the weighting factors is 100 percent. In the event that one or more of the stations cited in the command lack current OBS, SPC, or FCST information, the computer will automatically take action. The stations with current data will have their weighting increased proportionately to once again total to 100 percent. Whenever this re-weighting is done, a message will be issued warning the user that the display is based on fewer stations than intended.

It is possible to request a DSPU at a time when some of the requested stations have a forecast for today and others have tomorrow's forecast. To prevent a weighted product for two different dates, the SET DAYS command (See Section 1.4.7.1) takes on a new significance. Without a SET DAYS command the program will select those stations with a forecast valid for today. If tomorrow's forecast is desired, a SET DAYS -1 is required.

Since the same station can be called in any number of different DSPU commands and assigned different weighting factors, no station group facility like the S.I.G. (see Section 1.6) has been provided. To avoid the tedium of typing in several DSPU's each day with all the associated station data, create a command file (see Section 1.7) to be executed each day.

If two command files had been created earlier with DSPU700 containing the above example and FSTDU700 requesting forecasted DSPU's, the following example might result:

```
HH
U#=MAN68519,WHIZBANG,SMITH
NFDR '78 AFFIRMS (328/28/8/3)
FOR ASSISTANCE, CALL FTS 554-9458 OR COM (208) 384-9455

COMMAND:FILE READ DSPU700

FIL02I NOW EXECUTING FILE /DSPU700
--07/24/78--OBS---22:35MGT--
     DY     IC     MC   R
------------------------------
     24     27    3+    M
SYN06I END-OF-FILE ENCOUNTERED

COMMAND:SET DAYS -1
COMMAND:FILE READ FSTDU700

FIL02I NOW EXECUTING FILE 'FSTDU700'
--07/24/78--FCST--22:36GMT--
     DY   IC     MC      R
------------------------------
     25    46    4-      V
SYN06I END-OF-FILE ENCOUNTERED
COMMAND:BYE

TSP COST:  $ .65
0003.71  CRU    0000.01 TCH         0000.41 KC
OFF AT 15:35MST  01/24/78
```

In the above example, we obtained a DSPU for observed weather and a second DSPU for tomorrow's forecast weather. Note that the displayed manning classes always use the nine-class system (See appendix E).

1.6 ** THE SPECIAL INTEREST GROUP **

requently, users of AFFIRMS will find that they wish to display data from several tations which do not conform to any one geographical or political grouping. A ypical example would occur on the Tahoe National Forest in California. This orest adjoins the Toiyabe National Forest which is in a different region. The se of a display-by-forest would, because of the extent of the Toiyabe, supply ore data than the Tahoe would probably want to see. In such a case, a user would reate a list of stations from both forests, called a special interest group S.I.G.).

he SIG is an identifier for a list of station numbers. Use of the SIG 'scope' in display command has the same effect as use of the LIST scope with these station umbers. The SIG saves you the trouble of remembering the station numbers and he time necessary to type them. Since the SIG group does require additional verhead, try to use it when five or more stations are required. Use the LIST cope for fewer stations.

station can be in several different users' SIG's, because it may be of interest o users other than its owner.

.6.1 Locating A Free S.I.G. Number -- the SIG 999 LIST Command

S.I.G.'s are identified with a three-digit number. Since the groups are constructed in a random manner by the various AFFIRMS users, it is not obvious which S.I.G. identifiers are free. To locate a vacant S.I.G., enter this command:

```
COMMAND:SIG 999 LIST
INT111 AVAILABLE GROUP:  23
```

In this case, the computer had indicated that S.I.G. 023 is available. ***Note: The computer will not print a leading "0" but the "0" must be entered by the user, that is, you would use 023 to identify this SIG.

1.6.2 Maintaining the S.I.G. -- the SIG Commands

The SIG verb is used for maintaining a special interest group. One can: 1) add stations to the group, 2) delete stations from the group, 3) empty the group, or 4) list the group.

The forms of the command are:

SIG nnn,ADD,M1,M2,M3,.....;	Where nnn is the S.I.G. number, M1,M2,.... are 6-digit station numbers to be added to the S.I.G. SIG
nnn,DEL,M1,M2,M3,.....;	Where the M1, M2 ... are station numbers to be deleted.
SIG nnn,LIST;	The stations in the S.I.G. are listed.
SIG nnn,CLR;	All stations are removed from the group, and the owner's jurisdiction over the group ceases.

The S.I.G. number (nnn) must be three digits long (for example, 004).

If a SIG nnn ADD ... command is entered for a S.I.G. which is not already assigned, the S.I.G. is automatically assigned. If the S.I.G. is already owned, a message will be printed.

Requests to delete stations not in the list and/or to add stations already i the list will be ignored--no message will be given.

If you attempt to expand a S.I.G. to more than 20 stations, as many stations as can be accomodated will be added; the rest will be ignored. You can determine how many stations in your list were actually added because the up-arrow will indicate the first station which was **NOT** accepted from the ADD command.

If you list out a group and there are no stations in it, you will receive the message: GROUP EMPTY. If the group is not owned, you will get: GROUP UNASSIGNED.

.6.3 S.I.G. Examples

Here is an example of setting up a special interest group; the comments after each command describe its function:

```
COMMAND:SIG 999,LIST (Asking for the number of a free group)
INT11I AVAILABLE GROUP:  5

COMMAND:SIG 005,ADD,020209,021201 (this makes the S.I.G. "yours")

COMMAND:SIG 005,LIST (Checking the contents of the S.I.G.)
INTEREST GROUP CONTAINS THESE STATIONS:
020209 021201

COMMAND:SIG 005,DEL,021201,020209 (Deleting two stations)

COMMAND:SIG 005,LIST (Again, checking the contents)
INT04I GROUP EMPTY

COMMAND:SIG 005,CLR  (Freeing group back to  the pool)

COMMAND:SIG 005,LIST (The S.I.G. should now be free)
INT07I GROUP UNASSIGNED
```

1.7 ** FILES **

Files are created by users to make use of the computer's memory capabilities. Usually messages to be sent to other users (text files) or frequently used AFFIR commands (command files) are stored. You may create files (FILE MAKE), view the contents of a file (FILE LIST), execute the commands in a file (FILE READ), or delete a file from the computer (FILE PRGE). Only the creating user may purge a file. For instance, a fire weather narrative can be placed in a file; then, any user can view the file by using a FILE LIST command. The same user may have created a file containing the commands needed to display fire danger indexes; a FILE READ command is used to execute the commands in this file just as if they were entered from the terminal keyboard.

1.7.1 Generating a File---The FILE MAKE Command

In order to generate a file, respond to the computer's prompter, COMMAND:, typing FILE MAKE "name,", where "name" is the file's name.

File names must be four to eight characters in length, with the last three digits of your user number as the last three characters of the file name. For example, user number MAN68552 might make a file called JUNK552 or JU552 or even just J552. Using the last three digits of the use number in your file names assures that you will not select the same file na as another AFFIRMS user. Never use blanks, commas, periods, or any other special characters as part of a file name; the first character must be a letter. File names beginning with FWX are exempt from the user number requirement.

After you have supplied a file name, AFFIRMS will instruct you to enter the information you wish stored in the file, one line after another. When you have no more to enter, hit the break-key after the last carriage return. 1.3.2 for instructions on whole line repair. See 1.4.7.11 for instruction on creating a file from magnetic or paper tape.

Example:

```
COMMAND:FILE MAKE HEF309

FIL11I HIT 'RETURN', THEN 'BREAK' AFTER LAST LINE OF TEXT
READY FOR INPUT
JUNE 25/1300MDT

BOB, WHENEVER YOU ROUTE A MESSAGE TO FORECASTERS, INCLUDE
NUMBERS 005 and 010.
```

***Note: If you try to make a file with the same name as one you already have stored, a message will tell you so. You will be allowed to overwrite your old file with new text if you answer the 'want to overwrite' question with YES. Note that the new text would replace the old text; it is not added to the existing old text. If you type NO, the computer will return to the COMMAND: point and you must start over with a new FILE MAKE and another file name.

(Each line of text is ended with a carriage return. The Break-Key is hit after the last carriage return.)

.7.2 Viewing the Contents of a File --The FILE LIST Command

Once a file has been created, its contents can be reviewed with the FILE LIST command. The only requirement is that the user be able to supply the FILE NAME. Up to 19 names may be called in the same command.

Example:

```
COMMAND:FILE LIST OBS709
```

(At this point, the computer will print a complete copy of what user number 709 typed into FILE OBS709.

Frequently used file names that do not follow the general rules stated in 1.7.1 are:

FILE LIST BLURBS$L	See Section 1.2.6
FILE LIST SCHED$L	See Section 1.2.4
FILE LIST USRLST$L	See Section 1.2.7
FILE LIST FWXnnn	See Section 3.1.6
FILE LIST ARCSTA$L	See Section 4.2

1.7.3 Entering Commands from a Command File --The FILE READ Command

A file can consist of a series of valid AFFIRMS commands. Such a file is called a command file. If the file is executed using the FILE READ command AFFIRMS takes its commands from that file instead of the terminal's keyboar One might construct a file containing several display commands. Then, by entering a FILE READ command, the stored commands would be processed one after another. If this list of commands were needed every day, you would save the trouble of typing them each time they were needed.

Further, because the computer does not have to "read" your commands via you terminal, there is usually a dramatic increase in the speed with which the commands are carried out.

Example:

```
COMMAND:FILE MAKE R3WEA300

FIL11I HIT 'RETURN', THEN 'BREAK' AFTER LAST LINE OF TEXT
READY FOR INPUT

SET NAME ON
DSPI OBS STAT 29
DSPI OBS S1AT 02
```

Then each day, instead of entering those three commands separately, you could enter:

```
COMMAND:FILE READ R3WEA300
FIL02I NOW EXECUTING FILE 'R3WEA300'
```

AFFIRMS would execute the three commands in sequence and then expect its next command from your terminal's keyboard.

1.7.4 Producing Headings from a Command File -- The *

Whenever AFFIRMS finds a line in a command file preceded by an asterisk, *, it parrots it back on your printer. In this way, you can insert special comments or headings on output. This procedure consists of creating a command file which contains the needed commands with heading and comment lines inserted. The location of these marked lines in the file determines where they will appear on the output. For example:

```
*OBSERVED WEATHER AND INDICES FOR ARIZONA
DSPI OBS STAT 02
*THE FORECASTED FIRE DANGER INDICES FOR REGION 9 ARE:
DSPX FCST REG 9
```

The two displays obtained when this command file is executed with FILE READ will appear with those headings.

1.7.5 Obtaining A List of Saved Files--The FILE NAMES Command

Users commonly lose track of files which they have created. There are two ways to obtain a list of the files saved under your user number.

When you signoff on Mondays, AFFIRMS will automatically produce a list of the files saved under that user number. This will prevent creating a text file and then forgetting it. (Each file costs about $0.48 per month for the first 1,000 characters, and $0.48 for every additional 1,000.) An example follows:

```
COMMAND:BYE

(TSP) COST:  $0.54
EXC31I REMINDER: YOUR CURRENTLY-SAVED TEXT-FILES ARE:

SAVED FILE,    USER NUMBER AN68700
12/23/78           TIME 10:11MST
ZERO709  1 OCT     SAV709   5 NOV    MICH709    11 NOV

0001.15 CRU    0000.02  TCH     0000.72   KC

OFF AT 10:12MST   12/23/78
```

***-Note: When you receive this list of your existing files, check the date that each was last used. If any are obsolete, see 1.7.6 for instructions on purging them. If any file is not used for over 10 months, you will receive a warning message every Monday for 60 more days. If a file has not been accessed for over a year; it will automatically be purged and a message will advise you.

The second way to obtain this list is FILE NAMES. The computer will react as if BYE were typed on Mondays, except, instead of disconnecting the terminal, the computer will return to the COMMAND: point after the accounting is printed.

.7.6 Copying a File--The FILE COPY Command

Several user functions could require more than one copy of a file. For instance, if a message is to be POSTED to more than 19 other users, the route list for a single file would be exceeded (See Section 1.8.1). In this case, a second file with a different name could be created which would also have a potential of 19 recipients.

The form of the command is:

```
FILE COPY, 'name of the new file', 'name of the old file'
```

The old file does not have to belong to the user executing this command. All the rules for the new file name, however, are carried over from the FILE MAKE command (See Section 1.7.1).

An example of the command being used by User 709 follows:

```
COMMAND:FILE COPY,NEW709,OLD800
```

17.7 Purging a File--The FILE PRGE Command

To remove a file from the computer the FILE PRGE command is used. Only the user number that created a file may purge that file. An example command is:

```
COMMAND:FILE PRGE R3WEA300
```

Up to 19 file names may appear in this command.

17.8 Summary of FILE Commands

FILE COPY;	Create a new file with the contents of the original
FILE LIST;	Print the contents of one or more files.
FILE MAKE;	Create a text file.
FILE NAMES;	List the names of files saved under your user number.
FILE PRGE;	Remove one or more files from storage.
FILE READ;	Take commands from the file.

1.8 ** MANAGING COSTS

In almost every operation certain overhead costs exist. This basic rule has two cost impacts on the AFFIRMS user. First, if a toll telephone call is required to reach the computer port, a base minimum fee for 3 minutes is charged by the telephone company even if the session is completed in less than that time. The second overhead charge of approximately $0.30 is involved in just signing on and off the G.E. Timeshare System. Since the telephone charge is quite variable depending on location, it has not been included in the following examples. The base computer charge on the other hand is included in the figures used below.

Several factors determine the cost of putting data and commands into AFFIRMS. Th first is the number of operations sharing the overhead charges. Signing on to enter the fire weather observations for one station is more expensive on a per-station basis than signing on to enter data for 10 stations. The second poin involves the time it takes the operator to complete the session. Time affects both overhead charges. The telephone cost is figured on a 3-minute minimum and c each additional minute after that. The computer service, on the other hand, charges a flat rate of $12 per hour. Therefore, the sooner the session is completed, the lower the resulting cost. Several techniques are available which will decrease the time on the terminal. These remarks are aimed at particular groups of users. Therefore, consider each logically before adopting itsuse in yo application.

Output

Using Command Files: Once these files have been organized, the user references the file name with a FILE READ command. The computer is able to recall the file contents and execute the commands found there. Each command entered in AFFIRMS has an associated cost. Therefore, the contents of the file must be large enoug so that the saving in reduced typing time offsets the cost of the FILE READ command. If the operator is a fair typist, the command files need to be about lines long to make the command file pay. The convenience of automatic operation, however, might well justify files of only three lines. Finally, remember that each file costs $0.48 per month as a minimum.

Magnetic Tape: If your terminal has a paper or magnetic tape unit, the same saving is possible as with command files. The tape is started and stopped automatically by the computer as it reads one command at a time.

Selecting Display Commands: The relative efficiency of the different options for the display scope is discussed in Section 1.5.4. There are, however, other factors to consider. To minimize cost you should display only the data you need with the fewest possible number of the most efficient commands.

Since the DSPC allows you to display only the information that you wish to see, it should be used whenever the predefined displays give more information than is necessary.

Let us say that you are interested in 10 stations--five on your Forest and five on adjacent BLM land. Creating either a S.I.G. of 10 stations or using the LIST scope option would permit completing the operatiion with one command. On the other hand, if you displayed five stations with one command and the other station with a second, your costs would run about 30 percent higher than using one command.

Input

OBS, FCST, and ZONE commands can be entered using tape (via a command file, Section 1.7.2). The above comments concerning the utility of using these two input methods apply here, too. But, since the OBS, FCST, and ZONE commands change daily, a new tape must be made every day. Tape making and correcting is an art in itself, so a fair test of tape as an entry method will require considerable skill development before a valid comparison against keyboard entry can be made. The skill of the operator will determine that point at which the volume of data to be entered will make using tape pay. For a good typist who is proficient at making tapes, our experience is that the break-even point averages about 10 lines of input. If your input is more than 10 stations, a tape prepared and checked for errors "off line" will usually prove a better buy than "on line" keyboard entry.

1.9 ** ROUTED MESSAGES **

A useful administrative feature of AFFIRMS permits any user to route a message to other users in the AFFIRMS network. The procedure consists of putting a message in a text file and instructing the computer to print out that file automatically when a particular user signs on.

When any user signs on to AFFIRMS, his user number's last three-digits are checked to see whether they appear in a special route list that is generated by the message originator with the POST command. If the user's number is found in the list, he receives a copy of the message and his number is automatically removed from the list. Therefore, he receives the message only once, for each occurrence of his number in the list.

1.9.1 Sending A Message--The POST Command

An example of the POST command is:

```
COMMAND:POST Filename LLL,nnn,mmm,...
```

Where lll,mmm,nnn, etc. are the last three digits of the user numbers which are to receive the message. You can specify up to 19 numbers to this route list. The same user number may be entered more than once in the list; this causes multiple postings of the message to that user. The user numbers may be found in the USRLST$L explained in Section 1.2.7.

The file name specified for posting should already exist; you will have created it with FILE MAKE.

Only one route list for a specific file name may be in effect at any one time. Entering a POST command that cites a file which is currently posted simply overrides the earlier posting request and produces a new route list.

It is permissible for one user to enter a POST command which cites a text file owned by another user. But, if the owner purges it before everyone on the route list receives it, the first late comer will get an error message and the file will then be deposted.

1.9.2 Removing a File from the Route-List

Entering a POST command with a file name but no user number(s) causes the computer to erase the route list for that file.

1.9.3 Examining the Route List

Entering a POST command with no operands at all will display the current route lists.

Example:

```
COMMAND:POST

PST08I CURRENT POSTS
FILE     POSTED     FROM     TO
NAME       ON       USER     USER(S)

NEWD509  780809      509      503 504 505 506 508
```

File NEWD509 was posted on May 3, 1975 by user number 509. Users 503, 504,505, 506, and 508 have not yet received it. If other files had been posted, but not yet received by all users on their respective route lists, the above example would have included all of them.

1.9.4 Posting to AFOS Users

An interface system between AFFIRMS and the National Weather Service AFOS network will be implemented in the next several years. Most NWS AFFIRMS users will have AFOS terminals at their sites, and will access AFFIRMS through AFOS.

A regular AFFIRMS user can POST a message to an AFOS user (for example, the Fire Weather Forecaster) by placing a hyphen (-) in front of one or more user numbers in the POST command. For example:

```
COMMAND:POST BLM711 501 -551 502
```

AFFIRMS would post file BLM711 to two AFFIRMS users (501 and 502) and to user 551 via the AFOS network. The AFOS interface system will recognize that such a POST is intended for one of its users and will perform necessary posting within AFOS.

2. USING AFFIRMS -- THE FIRE MANAGER

2.1 ** THE STATION CATALOG **

The catalog is a community data file maintained by the users which contain permanent and semipermanent information about each of your fire-danger rating stations. By storing such information in the catalog, you are saved the trouble of repeatedly supplying it when you enter observations for that station. A station must be cataloged before weather data can be entered for it.

A station may be cataloged at any time, even weeks or months before it is ever actually referenced. In normal use, a station will be cataloged once prior to the first time that observations are entered for it.

Once a station is cataloged by a particular user, no other user can modify or destroy that station entry. Any user, however, can inspect any station catalog with the DESC command.

2.1.1 The Intitial Catalog Entry--The CTLG Command

The CTLG command makes the initial catalog entry for a station.

The following list contains a description of the operands for the CTLG command in their order of entry:

ID	The six-digit numerical station identifier. Obtain number from fire weather forecaster. Stations whose last two digits range from 90 to 99 are not archived, and are known as dummy stations. See appendix G for their use in prescribed burning.
ELEVATION	Feet above sea level, one- to five-digits.

TIME ZONE	The standard time zone in which the station is located (AST,EST,CST,MST,PST,YST,HST,BST) Note: Most Alaska stations should enter HST (Hawaiian Standard Time). AST means Atlantic Standard time.
FORESTOR UNIT NAME	A four-letter code for the National Forest or administrative unit in which the station is located. Forest names are to be represented by the first four letters or a phonetic abbreviation. BLM units can be shown as the first letter of the state and then BLM. BLM units in Nevada would then be NBLM.
REGION #	The USDA Forest Service Region number in which the station is located (1-10). Enter the number even if the station is run by an agency other than the Forest Service.
OBSERVING AGENCY	A one-digit code indicating the agency which operates the station. Use the following table: 1 Forest Service 2 Bureau of Land Management 3 National Park Service 4 Bureau of Indian Affairs 5 State Agency 6 City or County Agencies or Special Districts 7 Private or Commercial 8 Other Federal Agencies (such as DOD, NWS, and FAA) 9 Unknown

STANDARD OBS TIME	A two-digit number indicating to the nearest hour, the time at which the station normally takes fire weather observations (for example, 15 for 1500 hours). The time-of-observation entered in OBS and ARCH commands will be required to be within 2 hours of this standard observation time. Remember, Standard, not Daylight Savings Time.
FIRE WEATHER FORECAST ZONE	A three-digit number (001-999) assigned and used by the National Weather Service to designate the fire-weather forecast zone. The first digit usually corresponds with the Forest Service Region number (for example 503 is a fire weather zone in California).
STATION NAME	An entry of one to six alphabetic characters. It can be the complete or abbreviated name of the fire weather station. If any doubt exists about the clarity of the abbreviation, use all six letters.

If you refer to an already cataloged station in a CTLG command, the message CATALOG SUBSTITUTION is given. The net effect of such a recataloging is 1) the station's catalog entry is destroyed, 2) any current OBS, SPC, or FCST data for that station is destroyed, 3) the 1000 and x1000HR timelag fuel moistures, herbaceous and woody moistures, and herbaceous stage are destroyed, and 4) the command is processed and a new catalog entry created.

***-Note: A station catalog-entry is not completed until the HDEF, OPT, MODL, and LOC commands have also been given for that station. This must be done when intially cataloging a station, or when making a catalog substitution (recataloging).

Example of CTLG command:

```
COMMAND:CTLG 020202 6800 MST KAIB 3 1 13 308 MEADOW
```

This station's ID number is 020202; it is at an elevation of 6800 feet; in Mountain Standard Time Zone, on KAIBAB NF, in Region 3. Regular fire weather observations are taken by the Forest Service at 1300, and this station is part of Fire Weather Zone 308. The name of the station is Meadow.

2.1.2 Specifying the Humidity Variable--The HDEF Command

The HDEF command identifies the type of moisture-variable which AFFIRMS is t expect in OBS, SPC, or ARCH weather data from that specific station. Two operands are used with HDEF:

ID;	The six-digit station identifier
HUMIDITY CODE;	A one-digit number indicating the moisture variable to be entered.

1 = Wet-bulb temperature (Deg. F)
2 = Relative humidity (percent)
3 = Dewpoint temperature (Deg. F)
4 = Wet bulb (Deg. C) *
5 = Relative humidity (percent) *
6 = Dewpoint (Deg. C) *

The HDEF command must be given sometime between the time that a station is cataloged (or recataloged) and the first time that OBS, SPC, or FCST commar are used for that station.

The humidity variable specification may be changed at any time, as desired An example of the HDEF command:

```
COMMAND:HDEF 020202 1
```

We have specified that Station 020202 will enter wet-bulb temperature and English units for all other weather elements.

---

* Wind will be reported in meters/minute

2.1.3 Specifying Other Station Data --The OPT Command

The OPT command is used to determine optional station characteristics. The OPT command requires six operands:

ID	The six-digit station identifier
# of Display Classes	Number of manning classes being used by owning agency (3 to 9). See appendix E.
MI	Manning Index used by owning agency (see chart for manning index)
Associated Station	Number of a manual station from which man-observed items will be obtained if station being cataloged is an automatic station. Enter N if this not an automatic station.
Lightning Scaling Factor	Legal values may range from 0.01 through 5.0 with 1.0 as the default value.
Date on which Fuel stick was installed	Use form yymmdd

The MI operand is the abbreviation of the NFDRS component or index on which the manning guides of the suppression organization are based.

Manning Index (MI) Operand	Manning Index
IC	Ignition component
SC	Spread component
EC	Energy release component
MO	Man-Caused occurrence index
LO	Lightning-Caused occurrence index
BI	Burning index
FL	Fire load index

Example of the OPT command:

```
COMMAND:OPT 020202,3,BI,M,1.05,780703
```

We have specified that station 020202 will use three display classes, derive its manning class from Burning Index, has no associated station, has a lightning scaling factor of 1.05, and installed its fuel sticks on July 3, 1978.

You may enter M (missing) for those OPT command inputs which you want to leave unaltered. For example:

```
COMMAND:OPT 045691,M,M,045603,M,M
```

The above command would change the "associated station" specification while leaving the other items unchanged.

.1.4 Specifying the Station Location--The LOC Command

The station location is used to calculate changing day length, computer graphics, and for fire behavior interpolation of the standard observation to other locations and times of day. The operands for the command are:

ID	The six-digit identifier
LATITUDE	Degrees and decimals of degrees, so that 35 degrees 58 minutes is entered as 35.97
LONGITUDE	Entered in the same form as latitude
ASPECT	Indicate the direction in which the station slopes with any of the wind systems; eight-point number, 16-point number, 16-point letter, or degrees of the compass. See Note 4 of Section 2.2.3.
Site	A one-digit indicator for type of site: Valley bottom or flat 1 Midslope 2 Ridge or peak top 3

A sample of LOC command follows:

```
     COMMAND:LOC 020202,35.15,112.12,7,1
```

.1.5 Specifying the Station Fuel Model(s) --The MODL Command

The MODL command is used to select the fuel models, slopes, and manning levels that are to be used for a given station. Refer to the following table for descriptions of the operands and their order:

ID	The six-digit station identifier
CLIMATE CLASS	A one-digit number, either 1, 2, 3, or 4
FUEL-MODEL-SLOPECLASS-GRASSTYPE	A one-letter code for the fuel model (A to U only), a one-digit number (1,2,3,4,or 5 only) for slope class, and a letter (A or P) A = Annual; P = Perennial, indicating grasstype.
MI90&97	A four-, five-, or six-digit number indicating the 90th and 97th percentile values of manning index. For example, if the MI90 and MI97 were 4 and 12, respectively, you would enter 0412. A separate computer program named FIRDAT must be run against historical fire weather to obtain these values. (Where not known, enter 0000). (See Appendix E for information on how this entry is used.) See Section 4.5 for special instructions if the percentiles in the existing catalog need to be changed. DO NOT enter a new MODL command if the percentiles are the only change to be made.

Note: The Bureau of Land Management is using the 80th and 95th percentiles of the Burning Index, and the Forest Service, the 90th and 97th percentiles. If your agency mans on an index different than the BI, enter the appropriate percentile values for that component or index.

If more than one model is to be specified, repeat the fuel model name-slope class-herbaceous type-MI90&97. This command permits a variable number of operands; for one model, there will be 4 = (2+2), for two models, 6 = (2 +4), etc. The model specifications must always be grouped in pairs following the two header-operands. A maximum of four model-slope-grass type combinations can be specified for each station.

Here is an example of a MODL command specifying two fuel models:

```
COMMAND:MODL 020202 3 C2P 2440 B2A 86106
```

We have specified for station 020202, climate class 3, with two fuel models. The first is model C, slope class 2, with perennial grass, with MI90=24 and MI97 = 40. The second model is B, slope class 2, with annual grass, with MI90=86 and MI97=106.

*NOTE: When several combinations of Model-Slope-Grass type-MI90&97 are to be entered place the most important combinations first in the MODL command.

ANY TIME THAT A MODEL COMMAND IS ENTERED IT COMPLETELY OBLITERATES ANY PREVIOUS MODEL SPECIFICATIONS AS WELL AS THE CARRIED 1000HR AND X1000HR MOISTURES. THE HERBACEOUS AND WOODY VEGETATION CONDITIONS ARE ALSO ERASED. THEREFORE, IF A HERB AND OR WOOD COMMAND HAS EVER BEEN ENTERED IT MUST BE REENTERED ANEW ANYTIME THAT A MODL COMMAND IS USED. See Section 4.4 for instructions on reentering the 1000hr, x1000 and 100hr moistures after entering a MODL command.

1.6 Specifying the Herbaceous Vegetation Stage--The HERB Command

The HERB command permits you to declare the herbaceous-vegetation-stage for each fuel model used at a given station. The specifications can be changed any time as needed. The operands of the command are:

ID:	The six-digit identifier
MODEL-NAME;	A one-letter code for the fuel model which has been previously cataloged for this station
HERBACEOUS-VEGETATION.-STAGE	One of: GREEN, CURED, or FROZEN

To specify values for more than one fuel model, repeat the fuel model name-herbaceous state operands. For example, if a station used fuel models C and H, we could specify herbaceous green-up for the C and H models like this:

```
COMMAND:HERB 020209 C GREEN H GREEN
```

The order of the fuel models is not important. Also, one or more conditions can be specified without affecting those previously specified for the other fuel models.

Note that it is not permissible to specify PREGREEN or TRANSITION. Those stages can only occur when the program's curing computations dictate.

Three HERB commands can be entered by the user, each is used at a particular time. Enter GREEN each time the herbaceous plants react to improved growing conditions. This is usually once a year in the spring. Several times a year are possible in desert climates. The program greens up the model's living fuels at a rate set by the CLIMATE CLASS. One, 2, 3, or 4 weeks will be used. The choice will correspond to climates 1, 2, 3, or 4.

Enter FROZEN when cold temperatures kill herbaceous plants and force woody plants into dormancy.

Enter CURED when the program does not kill the herbaceous plants on a timetable matching phenological curing. It is also used to signal the death of herbaceous plants due to cold temperatures when the temperature is not low enough to effect woody plants. (See FROZEN above.)

The station actually has two Herbaceous stages: 1) the user input with the HERB command and 2) the program determined condition. Your input shows up in the station description with a DESC command (Section 2.1.7). The program determined stage shows as item 46 in the FORM-DSPC commands (Section 1.5.2.2).

.1.7 Specifying the Woody Moisture Content--The WOOD Command

The WOOD command is a special purpose feature reserved for those locations that actually collect and measure fuel samples of living branch wood and foliage. The purpose of this measurement is to tune up the internal calculation of the woody vegetation moisture content. Therefore, if actual measurements are not made, do not use this command.

The command has two operands, the station number and a moisture content. The maximum moisture content is 200, while the minimum value is determined by climate class, with 50, 60, 70, and 80 percent corresponding to the minimum values for climates 1, 2, 3, and 4. An example of the command follows:

```
COMMAND:WOOD 020202 105
```

The entered value will be used to guide the calculations for the next 30 days. If another measurement is not made within this period, a message is printed for 5 days warning of the stale wood data. After this period the program will compute the moisture internally without considering the old measured value.

.1.8 Listing The Station Catalog--The DESC Command

The DESC command causes the catalog for a specified station to be printed. The command takes 1 to 20 operands, each of which is a six-digit station identifier. An example of a DESC command:

```
COMMAND:DESC 041095

STATION  41095 WESTPK   CATALOG ENTRY (LAST MOD:0831/ 1330) CONTAINS:
USER-NUM:709, ELEV:2000, AGENCY:FOREST SERV., REG:5, UNIT:NFDR,
TIME:PST, OBS-TIME:1300, HUM-ENTRY:REL. HUM,  FWX-ZN:999
LAT/LONG:35.9/98.6, LIGHTNING SCALE FACTOR: 1.00
FORCED WOODY FM: 76.0  DATE MEASURED: 780831
FUEL-STICK DATE: 7781003
ASPECT: 45 (DEG.), SITE: VALLEY
MODELS:  A4A2     B3A2
HERB-STAGE:GREEN  GREEN
GREEN UP: 7805109    780601
(5) BI
LEVELS: 50./64.   100./120.
```

2.1.9 Removing a Station Catalog--The DEL Command

Do not delete your station catalog at the end of each fire season! It is cheaper to leave the catalogs in the computer. The storage cost of catalogs is paid as part of the AFFIRMS overhead costs.

The DEL command is used to remove a station from the catalog. The command takes just one operand, the six-digit station identifier. An example of the DEL command:

```
COMMAND:DEL 292503
```

We have requested that the catalog for station 292503 be removed from the AFFIRMS data file. Any reference to this station will now be cited as an error.

When the catalog entry is deleted, any current OBS, FCST, or SPC weather-and/or-indexes for that station will also be deleted from the Current Observation File (C.O.F.).

***-Note: If a station is deleted and then recataloged with the CTLG command, the OPT, HDEF, MODL, and LOC commands must be reentered.

2.1.10 Adding or Changing the Station Name--The NAME Command

The NAME command is used when a station was cataloged without a name or if the station name has changed and a correction to the catalog is desired.

```
COMMAND: NAME 482103 FOXPRK
```

After this command is entered, a DESC of 482103 will show FOXPRK as the station name, and FOXPRK will start the display line for 482103 if the SET NAME ON command precedes a display command. Only the owner of a catalog may change cataloged data.

.1.11 Changing the Station Fire Weather Zone--The FWXZ Command

Occasionally, the Fire Weather Forecaster will realine the boundaries of a fire weather forecast zone. At his direction, the land manager operating the affected station will use the FWXZ command to make this change. The rest of the catalog is not affected. The command form is:

```
COMMAND:FWXZ 020202 308
```

Following the execution of this command, a DESC of 020202 will show a change in the FWX-ZN value. Also, all forecasts or observations for this station residing in the C.O.F. will be flagged with the new FWX-ZN number.

Note that this command may be given only by the station's owner, not by the Fire Weather Forecaster.

2.2 ** ENTERING OBSERVED FIRE WEATHER DATA **

The displaying of fire weather and fire danger information, both observed and predicted, was covered in Section 1.5. Before information can be displayed, however, data must be entered into the computer for storage and/or processing. Fire management is normally responsible for putting fire weather observations into AFFIRMS. AFFIRMS then does the calculations necessary to produce the fire danger ratings and makes them ready for display upon request. The fire weather forecaster would normally be responsible for inputting the fire weather forecasts. In this section, we will look at the OBS, SPC, and ARCH, the commands used to enter the fire weather observations.

The weather data entered with OBS and SPC commands are used to compute fire danger indexes. Then the weather and the indexes are stored in a large random-access data file, called a Current Observation File (C.O.F.). This file is accessible to all users through the display commands. The new data replace any earlier data of the same type; that is, a new OBS would override the previous day's OBS data.

OBS and SPC entries are treated identically except that only OBS entries are used to determine yesterday's 100-hour and 1000-hour timelag fuel moisture value. The AFFIRMS program recognizes that these heavy fuels require many days to react to weather conditions. The current heavy fuel moistures are computed using observed weather and yesterday's fuel moistures. If the computer does not find an OBS less than 3 days old, "yesterday's" 10 and 100 hour fuel moistures are defaulted. If the data gap is more than 50 days the 1000-hour fuel moisture is also defaulted. The default values are selected by climate class.

When the entry of observations has been missed, more accurate heavy fuel moisture values result from entering the data using the DATE command to adjust the date, then the OBS command to enter weather data. The oldest data must be entered first. (Note that this will also archive data just as though an ARCH command were also entered.)

o prevent unauthorized entry of observations for a station, AFFIRMS checks to nsure that the user-number under which the station was originally cataloged atches that of the user who is attempting to enter an OBS, SPC, or ARCH command. he entry is ignored unless the user-numbers match.

hortly before midnight each day, AFFIRMS automatically copies any current OBS ata from the C.O.F. into a permanent archive. If archiving of noncurrent data is esired when regular-scheduled observations (OBS) are not entered, the ARCH ommand must be used. Data entered with this command are sent directly to the ermanent archive; no indexes are computed, the fuel moistures are not updated and he data are not stored in the C.O.F. Hence data are not accessible via the isplay commands. The format of the data in the permanent archive is given in ppendix H.

2.2.1 The Basic Fire Weather Observations--The OBS Command

OPERANDS FOR THE OBS COMMAND

Operand data	Type (see note 1)	Dec. Pt.	Min. Len.	Max. Len.	Min. Val.	Max. Val.	Missing-Ok (see note 2)
Station #	Num.	No	6	6	010101	509999	Never
Obs. time	Num.	No.	2	2	01	24	Never
State of Wx (See Note 8)	Num.	No.	1	1	0	9	Never
Dry-bulb temp.	Num.	Optional	1	4	-100	136	Never
Hum. entry (See Note 3)	Num.	Optional	1	3	Varies	Varies	Never
ML (Morning's (lgt. act. lvl, Note 9)	Num.	No	1	1	1	6	Never
Man risk	Num.	No	1	3	0	100	Never
Wind direct. (See Note 4)	Mixed	No	1	3	Varies	Varies	Anytime
Windspeed	Num.	No	1	2	0	99	Never
10-Hr-T/L moisture	Num.	Optional	1	4	1	99	Station
Max. temp.	Num.	No	1	3	Dry-B	136	Station
Min. temp.	Num.	No	1	4	-100	Dry-B	Station
Max. RH	Num.	No	1	3	Obs.RH	100	Station
Min. RH	Num.	No	1	3	1	Obs.RH	Station
Precip. amt. (See Note 6)	Mixed	Required	1	5	0.00	9.99	Never
YL (Prev. day's lgt.act.lvl., Note 9)	Num.	No	1	1	1	6	Never
Forecasted MC-Risk (See Note 7)	Num.	No	1	3	0	100	Never
UNKO (See Note 10)	Mixed	No	0	8	Varies	Varies	Anytime

Because automatic archiving of OBS data takes place at 2300 MST each night, it is important that AFFIRMS users avoid entering OBS commands between hours indicated below:

Bering Standard	7 p.m.	8 p.m.
Hawaiian Standard	8 p.m.	9 p.m.
Alaskan Standard	8 p.m.	9 p.m.
Yukon Standard	9 p.m.	10 p.m.
Pacific Standard	10 p.m.	11 p.m.
Mountain Standard	11 p.m.	Midnight
Central Standard	Midnight	1 a.m.
Eastern Standard	1 a.m.	2 a.m.
Atlantic Standard	2 a.m.	3 a.m.

2.2.2 The "special" observation and archiving "missed" regular observations--the SPC and ARCH commands

OPERANDS FOR THE OBS COMMAND

Operand data	Type (See Note 1)	Dec. Pt.	Min. Len.	Max. Len.	Min. Val.	Max. Val.	Missing-Ok (See Note 2)
Station #	Num.	No	6	6	010101	509999	Never
Obs. time	Num.	No.	2	2	01	24	Never
State of Wx	Num.	No.	1	1	0	9	Never
Dry-bulb temp.	Num.	Optional	1	4	-100	136	Never
Hum. entry (See Note 3)	Num.	Optional	1	3	Varies	Varies	Never
ML (Morning's (lgt. act. lvl, Note 9)	Num.	No	1	1	1	6	Never
Man risk	Num.	No	1	3	0	100	Never
Wind direct. (See Note 4)	Mixed	No	1	3	Varies	Varies	Anytime
Windspeed	Num.	No	1	2	0	99	Never
10-Hr-T/L moisture	Num.	Optional	1	4	1	99	Station
Max. temp.	Num.	No	1	3	Dry-B	136	Station
Min. temp.	Num.	No	1	4	-100	Dry-B	Station
Max. RH	Num.	No	1	3	Obs.RH	100	Station
Min. RH	Num.	No	1	3	1	Obs.RH	Station
Precip.dur. (See Note 5)	Num.	No	1	3	-24	23	Never
Precip. amt. (See Note 6)	Mixed	Required	1	4	0.00	9.99	Never
YL (Prev. day's lgt.act.lvl., Note 9)	Num.	No	1	1	1	6	Never

.2.3 Explanatory Notes for OBS, SPC, and ARCH Commands

***-Note 1: "Type" refers to the kind of character allowed; "Num." indicates numbers only; "Alpha", alphabetical letters only; "Mixed", numerical or alphabetical.

***-Note 2: Under "Missing OK": "Never" means the data are always required; "Anytime" means the data are not required (but may be entered, for the record); if it is not entered, an M must, however, be typed in that location; "Station Dep." means the data should be entered if available to improve the accuracy of fuel moisture computations.

***-Note 3: Humidity may be entered as wet-bulb, relative humidity, or dewpoint temperature. The selection is made using the HDEF command. The selection once made stays in effect for all future entries until another HDEF command is given (see Section 2.1.2).

***-Note 4: Wind direction may be entered in regular 8-point one-digit form, in 16-point two-digit form, in degrees-of-the-compass three-digit form, or in 16-point letter codes. Thus, all of the following would give the same wind direction (the direction is stored and archived as eight-point): 1,02,045,NE. (If 0 entered for Windspeed then a 0 or M must be entered for Direction.)

***-Note 5: "Fuels Wet" can be indicated by entering the Precip. Dur. as a negative number. For example, if the actual precipitation duration was 3 hours, you would enter -3 if fuels were still wet. If snow or ice still cover the sticks, but no precipitation has fallen that day, enter -0. Any negative number sets all indices to zero.

**-Note 6: For an amount less than 0.005 enter "T" (trace). (If T is entered, you must enter at least 1 in Duration.) A decimal point is not required if the amount is zero.

***-Note 7: Forecasted Man-Caused Risk is entered in OBS command only. This value is then automatically used as the Man-Risk in any subsequent FCST display. This feature permits the Man-Risk to be entered at the Forest leve (via OBS).

***-Note 8: States of the weather 5, 6, or 7 (drizzle, rain, and snow) cause all indexes to be set to zero because generalized precipitation over the protection unit is assumed. States of weather 8 and 9 assume localized precipitation and will not zero out all indexes.

***-Note 9: ML is the lightning activity level which best describes the lightning situation from midnight to basic observation time. YL is the lightning activity level for the entire previous day. YL cannot be less tha the ML from yesterday's observations. See appendix I for the use of the lightning activity level.

***-Note 10: The UNKO field consists of 0 to 6 letters or numbers in any format (Do not use spaces, commas, semicolons or slashes.) It may be used to send any type of local interest information in codes or format of your choice, fc example, cumulus cloud build-up status, altimeter setting, etc. The UNKO field appears in DSPW OBS displays and may also be seen DSPC displays.

2.2.4 Examples of Use of OBS, SPC, ARCH Commands

Here are some examples of OBS, SPC, and ARCH commands:

```
COMMAND:OBS 020202 13 1 95 25 1 37 NE 12 35 100 69 35 21 1 .01 44
COMMAND:SPC 020202 13 1 95 25 1 37 NE 12 35 100 69 35 21 1 .01 1
COMMAND:ARCH 020202 13 1 95 25 1 37 NE 12 35 100 69 35 21 1 .01 1
```

(Note that the SPC and ARCH commands are identical to the OBS command if th predicted Man-Risk, the last OBS operand, is removed. See exhibits I and II in the sample works sheets at the back of this publication.

Here is a typical sequence showing the use of the ARCH command to archive data which was not entered the day the observations were made. First, the system date is set as necessary (See Section 1.4.6). Then one or more ARCH commands follow. The Break-Key is hit after the series to revert the date back to today's. If a second set of ARCH commands follow the first, do not hit the break-key, but rather enter another DATE command and continue with the next ARCH set.

OBS commands could replace the ARCH commands in this example if the DATE commands were in past-to-present order and no OBS had been entered which postdates the DATE commands.

Note: If the herbaceous vegetation stage has changed during the inactive period that the ARCH command covers, a HERB or WOOD command can be given in the same date order.

```
COMMAND:DATE 79/04/15   (first we set the date back as needed)
EXC04I DATE OVERRIDDEN 79/04/15

COMMAND:ARCH 020202 13 1 85 35 1 45 NW 7 23 90 68 52 25 1 .03 2
    (This archives the stale data for 020202 see worksheets at
    end of publication exhibit III)

COMMAND:ARCH 020601 13 1 84 37 1 52 N 6 26 89 67 45 31 0 0 1
   (DATE command still in effect, archiving for 020601)

COMMAND:HERB 020202 C Green (Changing herbaceous vegetative condition
                            for succeeding ARCH or OBS commands.)

COMMAND:DATE 79/04/16  (Continue the archiving session)

COMMAND:ARCH 020202 13/3/48 90 1 25 NW 4 20 50 35 100 80 -5 .47 1
  (This archives weather data for April 16, 1979 including the
  green-up date of the herbaceous vegetation which was put in catalog
  storage by the HERB command.)
```

For greatest efficiency, you should use a series of ARCH commands (for several days and/or stations) in one session, rather than signing on each da to put in one ARCH command. If several ARCH commands are entered for the same date and station, only the last entry will be permanently saved. This feature allows correction of errors by rearchiving the data.

***-Note: Sample worksheets are included at the end of the publication. reproduced and used to assist in the encoding of OBS, SPC, and ARCH commands. Exhibit 2 is for SPC and ARCH commands. The SPC and ARCH commands are identical to the OBS command if the last column, Man-Risk is left off the O form.

2.2.5 Entering Stale Observational Data

To avoid the requirement for entering the date for each observation the program assumes that any data entered is for today's date. If an observation is taken and not entered on the same day, special steps must be taken to notify the system of the correct date. The DATE command performs this function. See Section 1.4.6 for details concerning the DATE command.

Two techniques are available for inputting missed observations. An OBS or ARCH command may be used after the DATE command to process the data.

The ARCH command is a direct entry method that insures that the observatio is stored for future use at the National Fire Weather Data Library. It doe no calculations. Therefore observations entered in this way do not bring t 100, 1000, x1000, herbaceous or woody fuel moistures up to date. Since no calculations are made, the data can be entered for any past date, even yea ago. The other consequence of skipping the calculations is that the comma has a low cost. These two facts, no calculations and low cost, make the A command the best choice for correcting data entered in error or missed fro early in the season or in other years.

The OBS command entered after a DATE command accomplishes the same permanent storage of the observation as the ARCH. In addition, it also does the normal daily computations. Since computations are being done, the sequence of DATE and OBS commands must fill in any gap in the records (from oldest to newest). Computation makes this technique more expensive than the ARCH. As each observation is processed, it replaces a data file for OBS that is available to all users. Therefore, if the user wishes to display the results of a series of DATE and OBS commands, the display commands must also be placed in the series before the next DATE command.

.3 Obtaining the Fire Weather Forecast Narrative

Predicted fire weather usually consists of such forecasted weather elements as temperature and wind and a narrative describing the expected weather. To obtain the narrative, the FILE LIST FWXnnn command is used. The nnn represents the three-letter airport abbreviation used by the National Weather Service. (See Section 1.2.7 for instructions on obtaining the three-letter abbreviations from USRLST$L). A sample command is:

```
COMMAND:FILE LIST FWXBOI
```

This command would give you the current forecast fire weather narrative issued by the Boise Office of the National Weather Service.

3. USING AFFIRMS -- THE FIRE WEATHER FORECASTER

3.1 ** ENTERING FIRE WEATHER FORECASTS **

Affirms allows considerable flexibility to the forecaster as regards the entry of forecasted weather information. The FCST command is used to enter forecasts of the absolute values of meteorological variables for a station or series of stations. The ZONE command allows a trend forecast to be supplied to a group of stations within a fire weather forecast zone or to a single station.

3.1.1 The Point Forecast -- The FCST Command

The weather data entered using the FCST command is used to compute predicted fire danger indexes. Then the weather and the indexes are both stored in a large random-access data file, called a Current Observation File (C.O.F.). This data file is accessible to all users via the display commands. The new data replaces any earlier data of the same type; that is, a new FCST would override the previous day's FCST. Data entered with FCST is valid for the current date plus one day (that is, tomorrow's date).

OPERANDS FOR THE FCST COMMAND

Operand data	Type (See Note 1)	Dec. Pt.	Min. Len.	Max. Len.	Min. Val.	Max. Val.	Missing-Ok (See Note 2)
Station #	Num.	No	6	6	010101	509999	Never
Valid time	Num.	No.	2	2	01	24	Never
State of Wx	Num.	No.	1	1	0	9	Never
Dry-bulb temp.	Num.	Optional	1	4	-100	136	Never
Relative hum. (See Note 3)	Num.	Optional	1	3	Varies	Varies	Never
AL (Afternoon's (lgt. act. lvl)	Num.	No	1	1	1	6	Never
TL (Tomorrow's lgt. act. lvl, See Note 4)	Num.	No	1	1	1	6	Never
Wind direct.	Mixed	No	1	3	Varies	Varies	Anytim
Windspeed	Num.	No	1	2	0	99	Never
10-Hr-T/L moisture	Num.	Optional	1	4	1	99	Anytim
Max. temp.	Num.	No	1	3	Dry-B	136	Never
Min. temp.	Num.	No	1	4	-100	Dry-B	Never
Max. RH	Num.	No	1	3	Obs.RH	100	Never
Min. RH	Num.	No	1	3	1	Obs.RH	Never
Precip. dur. 1 (See Note 7)	Num.	No	1	2	0	16	Never
Precip. dur. 2 (See Note 7)	Num.	No	1	2	-8	7	Never

3.1.2 The Trend Forecast -- The ZONE Command

The Zone command is designed to simplify the work of the fire weather forecaster. When the forecaster normally issues trend forecasts for a fire-weather zone instead of specific values for individual stations, the ZONE command should be used instead of the FCST command.

When the forecaster enters a ZONE command, the trends are automatically applied to all current observations for stations located in that zone. Then, AFFIRMS generates forecast entries for each station, just as if the forecaster had entered a separate FCST command for those stations.

If one or more stations in the zone require a special forecast (that is, the trend does not apply to them), the FCST command can be used to override the ZONE forecast.

If experience shows that a station's fire weather zone should be changed, use the FWXZ command (Section 2.1.10). This command permits a change of zone number without the expense and effort of recataloging the station.

*-Note: If the current day's observation for a station is not entered into AFFIRMS before the ZONE forecast, there will be no forecast made for that station that day. If there are no current OBS commands for any station in a zone, the forecaster will receive a message with that information. A series of FCST commands would then be needed for the missing stations. Since FCST commands contain absolute weather elements rather than trends, the computer can produce a forecast without current weather observations.

OPERANDS FOR THE ZONE COMMAND

Operand data	Type (See note 1)	Dec. Pt.	Min. Len.	Max. Len.	Min. Val.	Max. Val.	Missing-Ok (See Note 2
Zone number (See Note 11)	Num.	No	3	3	001	999	Never
Region number	Num.	No.	1	2	1	10	Never
Valid time	Num.	No.	2	2	01	24	Never
State of Wx (See Note 10)	Num.	No.	1	1	0	9	Never
Dry-B tmp.trend	Num.	Optional	1	3	-40	+40	Anytime
Rel-hum. trend (See Note 3)	Num.	Optional	1	3	-90	+90	Anytime
Windspeed trend	Num.	No	1	3	-40	+40	Anytime
Precip. dur. 1 (See Note 7)	Num.	No	1	2	0	16	Never
Precip. dur. 2 (See Note 7)	Num.	No	1	2	-8	7	Never
Max.-tmp. trend (See Note 8)	Num.	No	1	3	-40	+40	Anytime
Min.-tmp. trend (See Note 8)	Num.	No	1	3	-40	+40	Anytime
Max.-RH trend (See Note 8)	Num.	No	1	3	-90	+90	Anytime
Min.-RH trend (See Note 8)	Num.	No	1	3	-90	+90	Anytime
AL (Afternoon's (lgt. act. lvl)	Num.	No	1	1	1	6	Never
TL (Tomorrow's lgt. act. lvl) (See Note 4)	Num.	No	1	1	1	6	Never
10-HR-T/L moisture (see Note 9)	Num.	Optional	1	5	-65	+65	Anytime

.1.3 Explanatory Notes for the FCST and ZONE Commands

***-Note 1: "Type" refers to the kind of character allowed; "Num." indicates numbers only; "Alpha." means letters only; "Mixed" means numeric or alphabetic.

***-Note 2: Under "Missing OK"; "Never" means the data are always required; "Anytime" means the data are not required, but may be entered for the record (if it is not entered, an M must be typed in to fill that location). When an M is permissible and is used with the ZONE command, it will be treated as a zero trend (persistence).

***-Note 3: For FCST commands, the humidity variable is automatically assumed to be relative humidity, regardless of the HDEF in effect for the station. "SET DWPT ON" may be used if you wish to enter dewpoint instead. (See Section 1.4.7.6)

***-Note 4: AL is the predicted lightning activity level (LAL) for this afternoon and evening from basic observation time to midnight. TL is the predicted LAL for tomorrow, midnight to midnight. See appendix I for the use of LAL.

***-Note 5: Wind direction may be entered in regular eight-point one-digit form, in 16-point two-digit form, in degrees of the compass three-digit form, or in 16-point letter-codes. Thus, all of the following would give the same stored wind direction (the direction is stored internally as eight-point):

1, 02, 045, NE,

***-Note 6: Used if entered in FCST commands. If entered as missing, it is computed from the temperature and humidity forecast for basic observation time. (See Section 3.1.7)

***-Note 7: "Fuels Wet" can be indicated by entering the Precip. Dur. as a negative number. For example, if the precipitation duration was forecasted to be 3 hours, and fuels were expected to be wet at the forecast valid time, you would enter -3. "Precip. Dur. 1" is for the first 16 hours; "Precip. Dur. 2" for the last 8 hours of the 24-hour period between basic observations. If you expect the fuels to be covered by ice or snow that fel before this 24-hour period, predict a -0 (minus zero) for "Precip. Dur. 2". All indexes will be forced to 0 (zero) if a negative duration is forecast.

***-Note 8: If it is desirable to forecast the average 24-hour temperature and relative humidity, enter the same trend for both the Max. and Min. forecaste values. This will have the same effect as trending the averages.

***-Note 9: If the 10-HR T/L trend is entered as missing, the forecasted 10-HR moisture will be computed as shown in Brugan and others, 1978 (INT-40)*. If a trend is entered, it will be applied to the 10-HR T/L moisture value taken from the observation on which the forecast is based. Zero trend must be enter as 0 not M.

***-Note 10: States of weather 5, 6, or 7 (drizzle, rain, and snow) cause all indexes to be set to 0 (zero).

***-Note 11: A single station number may be used instead of a zone number, in which case, the trend is applied to that single station only. This is equivalent to a zone containing just one station.

3.1.4 Temporary Station Groupings--The STOW Command

There are times when fire weather forecasters wish to apply the same station forecast to more than one station, or the same zone forecast to more than on fire weather zone.

---

*Burgan, Robert E, Jack D. Cohen, and John E. Deeming. 1978. Manually Calculating Fire-Danger Ratings - 1978 National Fire Danger Rating System. USDA Forest Service General Technical Report INT-40. Intermountain Forest & Range Experiment Station, Ogden, Utah.

The STOW command permits this kind of blanket forecast to be made. The STOW command places up to 19 station-numbers or 19 fire-weather zone numbers into a temporary "stow" group within AFFIRMS. This "stow" exists only for the duration of that AFFIRMS session. The command takes two forms:

COMMAND:STOW ID,111111,mmmmmm,nnnnnn (where 111111, etc. are station identifiers)

COMMAND:STOW ZONE,111,mmm,nnn (where 111, etc. are fire weather zone identifiers in the Forest Service Region)

The "stow" is held until another STOW overrides it.

The "stow" is then utilized by using the word STOW in place of either the zone-number (as in a ZONE command) or the station-number (as in a FCST command).

***-Note: The "stow" is eliminated at the end of the AFFIRMS session or whenever another STOW command (of the same type, ID or ZONE) is entered.

***-Note: No ZONE command may apply to more than 40 stations, whether in a single zone or a "stow" group.

3.1.5 Examples of FCST, ZONE, and STOW Commands

Here are examples of the FCST and ZONE forecasts:

```
COMMAND:FCST 020202,13,1,95,25,2,3,NE,12,M,100,71,36,21,1,4
    (There is no forecast of the 10-HR T/L fuel moisture.)
```

```
COMMAND:ZONE 311,3,13,1,5,-2,0,1,5,3,-2,-2,1,1,-5
```

In the FCST example, the prediction relates to station 020202 only; in the ZONE example, the trends will be automatically applied to the current observations of all the stations in forecast zone 311 in Forest Service Region 3.

***-Note: In the sample worksheets at the end of this publication exhibits 3 a 4 can be reproduced and used to assist in encoding of FCST and ZONE command

Here is an example of using the STOW command. First, tell the computer whi stations (forecast zones) that the FCST STOW (ZONE STOW) is to be applied t and then enter the appropriate STOW command.

```
COMAMAND:STOW ID,020202,020203,020204
```

```
COMMAND:FCST STOW,13,1,95,25,2,3,NE,12,M,100,71,36,21,1,3
```

The identical FCST command will be applied to stations 020202, 020203, and 020204.

```
COMMAND:STOW ZONE 301,302,303
```

```
COMMAND:ZONE STOW,3,13,1,5,-2,+2,0,1,+5,+4,-2,1,1,-5
```

The identical trends specified in the ZONE command will be applied to all stations in fire weather zones 301, 302, and 303 in Forest Service Region

***-Note: The F.S. Region number is the first operand after ZONE STOW verb. Before a ZONE STOW... command can be used, a STOW ZONE command must precede it sometime during the session. Likewise, a FCST STOW... command must be preceded sometime during the session by a STOW ID... command. Failure to do this will result in an error message and a request for a new command.

.1.6 The Forecast Narrative

It is customary for narrative descriptions of synoptic patterns, trends, outlooks, etc. to be part of the fire weather forecast. AFFIRMS allows such information to be communicated to the fire manager through a text file (see the FILE MAKE command, Section 1.7.1). It is only necessary for the fire manager to know the name of the text file that contains the narrative. He can retrieve the narrative with the FILE LIST command.

File names for these narratives are designated as follows:

FWXwww

Where the www is the alphabetic identifier of the Weather Service Forecast office. For instance, FWXLAX represents Los Angeles. The alphabetic identifiers for all NWS Forecast Offices entering data into AFFIRMS are in the USRLST$L file. Section 1.2.7 explains how to get a copy of USRLST$L.

If several narratives are routinely issued from one forecast office, they might be designated by appending a number. For instance: FWXLAX1, FWXLAX2, and FWXLAX3.

An example of a forecast narrative can be found in appendix A.

3.2 ** AMENDING THE FIRE WEATHER FORECAST **

If a forecast, whether issued as a FCST or ZONE command, requires amending the same day as the original forecast, no special procedures are required. Simply enter the amended forecast the same way as you would enter the original.

If the forecast requires amending the next day (the day the original forecast was valid for), the DATE command must be used first (see Section 1.4.6). It is necessary because the date assigned to the forecast by the computer is the curren day plus 1 (Section 3.1.1). If you attempt to enter a ZONE command without resetting the date, you will get an error message because there will be no observations found in the C.O.F. with today's date. If you use the FCST command, the valid date would be tomorrow's (today's date plus 1).

Example of amending a forecast on June 28 which was originally issued on June 27:

```
COMMAND:DATE 78/06/27

EXC041 DATE OVERRIDDEN 78/06/27

COMMAND:ZONE 311,3,13,2,7,-1,4,2,1,4,4,-1,-1,2,2,12

COMMAND:(Operater hits Break-Key to revert date) to June 28)

EXC091 DATE REVERTED (Computer response)

COMMAND: (continue business).
```

. USING AFFIRMS -- THE REGIONAL FIRE MANAGER

4.1 ** SCREENING LARGE STATION GROUPS **

o permit managers with large numbers of stations to selectively display a few tations, the screening SET commands were introduced.

.1.1 Screening by Manning Class -- The SET MC Command

In the following example a user wished to sort through all 220 California stations and to see only those stations that were in manning plans 4+ and 5:

```
COMMAND:SET MC 4+

COMMAND:DSPX OBS STAT 04
```

The following values are possible MC minimums:

0 1- 1+ 2- 2+ 3- 3+ 4- 4+ 5

.1.2 Screening by Adjective Class -- The SET AC Command

In the following example, the manager would see only those stations in Very High or Extreme Adjective Class:

```
COMMAND:SET AC VH
COMMAND:DSPX OBS STAT 04
```

The following values are acceptable AC minimums:

0 LO MD HI VH EX

4.1.3 Double Screening

As was pointed out in Section 1.4.7.6, all SET commands can be mixed on one line. In this example, the user has said, "show me only those stations with MC equal to, or above 4+, AC of EX, and produce these displays with station names."

```
COMMAND:SET MC 4+,AC EX,NAME ON
```

***-Note: To return the SET command above to the "normal" state, either sign off or:

```
COMMAND:SET MC 0,AC 0, NAME OFF
```

4.2 ** MONITORING REGIONAL OBSERVATIONAL ACTIVITY

Each night at 2300 MST, the archiver program searches the current observation file and copies that day's OBS records into permanent storage. This copy process produces an accounting file indicating how many new records orginated in each Forest Service Region. This example shows how this accounting file may be listed:

```
COMMAND:FILE LIST ARCSTA$L

ARC01I START 07/30/78 AT 23:15MDT
ARC026I EXTENT AT OPEN:  5042
ARC02I  368 RECORDS COPIED FROM 'ARCMOD$S'
ARC03I  REG: 1,   66 OBS,     31 FCSTS
ARC03I  REG: 2    59 OBS,     65 FCSTS
ARC03I  REG: 3    49 OBS,     49 FCSTS
ARC03I  REG: 4    80 OBS,     83 FCSTS
ARC03I  REG: 5    15 OBS,     13 FCSTS
ARC03I  REG: 6   224 OBS,    229 FCSTS
ARC03I  REG: 8     0 OBS,      0 FCSTS
ARC03I  REG: 9    12 OBS,     37 FCSTS
ARC03I  REG: 10   48 OBS,     61 FCSTS
ARC08I 'STOP' 07/30/78 AT 23:21MDT (908.7 CRU) EXTENT: 6531
```

The line referring to records copied from ARCMOD$S reports on the total numbers of observations entered with the DATE-ARCH or DATE-OBS command combination.

Please inform the AFFIRMS staff of large changes of use such as many stations coming on the system in the spring and terminating use in the fall. When your region's AFFIRMS activity is reduced at the end of fire season, the staff can reduce community file sizes and save considerably on storage charges.

4.3 ** LINKING TO ANCILLARY ROUTINES **

Several Ancillary Routines have been provided to organize and display the data base supporting the AFFIRMS system. The objective is to provide the Regional or State level manager with the ability to get an overview of what is being done in his area. These routines can be accessed via the LINK command.

4.3.1 Summarized Station Catalogs for Regional Areas-- The LINK CTLDMP$C Command

The routine produces a list of all the stations cataloged within a particular Region. The total station catalog is condensed into one line containing station number, elevation, time zone, Forest or unit abbreviation, operating agency code, basic observations time, Fire Weather Zone, latitude, longitude, station name, and the AFFIRMS user number of the owner.

Example:

```
     COMMAND:LINK CTLDMP$C

     **AFFIRMS ANCILLARY ROUTINES: CATALOG DUMP

     DO YOU WANT ALL REGIONS (YES/NO):NO  (You type in yes or no)
     WHICH REGION NUMBERS:3  (You supply the Region number)
     STATIONS STASHED IN CATALOG REGION 3:

STATION  ELEV  ZONE  FOR.  REG  AG  TIME  FWX  LAT    LONG    NAME    USE
20104    6500  MST   ABLM   3   2    13   433  36.30  113.10  TRUMB   407
20202    6800  MST   KAIB   3   1    13   308  36.15  112.12  CLOVER  300
20203    7500  MST   COCO   3   1    13   308  34.40  111.25  HPYJCK  300
20207    6700  MST   KAIB   3   3    13   303  35.20  111.40  TOSAYN  300

     TOTAL OF 4 STATIONS IN REGION
     ------------------------------------------
     COMMAND:
```

.3.2 Listing S.I.G. Contents -- The LINK SIGDMP$C Command

This routine displays an accounting of all the S.I.G.'s giving the S.I.G. number, the owner, date of last use, and the station numbers. The example has been cut short to save space, but had it run to completion, it would have returned with the prompter:

```
COMMAND:
```

```
COMMAND:LINK SIGDMP$C

**AFFIRMS ANCILLARY ROUTINES: SPECIAL-INTEREST GROUP DUMP
WANT STATION NUMBERS (YES/NO):YES

CURRENTLY ASSIGNED S.I.G.'S
AS OF     15:46GMT    12/14/78

   001     304      7/78   20209     20203
   002     304      7/78   20202     20207     20210
   003     310      7/78   20501     20502     29201     29205
   004     305      7/78   21201     21201     21301     21403
   005     501      7/77   45326     45318     45328     45323     45301
                           45325     45305     45313     45321     45324
                           45311     45307     45316     45306
   006     508      8/77   41406     41005     41101     41503     41402
```

**-Note: The objective in producing this listing is to help call attention to nefficient operations or SIG numbers no longer in use. The S.I.G. proves to be ore expensive than any other display scope (see 1.5.4) except the FOR and UNIT ntil the group contains five or more stations. On that criteria, S.I.G.'s 0013 hrough 004 should be emptied and a display with LIST scope used instead.

4.3.3 Modifying The Current Observation File -- The LINK COFMOD$C Command

The 1978 version of the National Fire Danger Rating System introduced the 1000-hour timelag fuels. A six-week period of observations is required for the computations of these large fuels to converge with the actual value of the fuels in the field. The MODL command effects the records in which these computed values are stored. As a result, anytime that a MODL command is entered, it destroys the stored values for the 1000, x1000, 100, herbaceous, and woody moistures as well as the herbaceous stage and the green-up date. See Section 4.5 for modifying the manning percentiles.

The LINK COFMOD$C command connects the user with an ancillary routine that can restore these values if the MODL command must be used during the fire season. If a MODL command is to be entered a form command and DSPC (see Section 13.5.21) must be entered first to find the present 1000, x1000, herbaceous and woody moisture values, and the herb stage. The following sequence of steps should be followed to restore the station.

1. Enter new MODEL command.

2. Enter a DATE command with yesterday's date and follow it with yesterday's OBS.

```
COMMAND:DATE yymmdd (yesterday's year, month, and day)

COMMAND:OBS ........................... (yesterday's OBS)
```

3. If a HERB command setting the green-up date has been entered at a previous time that season, it must be preceded by a DATE command and reentered.

```
COMMAND:DATE 78 06 01 (enter the green-up date)
COMMAND:HERB 041095 C GREEN B  GREEN
```

- If a WOOD command has been entered reporting a measured woody moisture content in the last 30 days, it must also be preceded by a DATE command and reentered.

- Use the BREAK KEY to return the internal date to today.

```
    COMMAND:(break key)
```

- Link to the COFMOD$C routine. The routine will ask for the station number. Next it will provide a list of six things that can be modified. Enter the label for the item to be set and the program will then request the value or values needed to satisfy that field. The HERB and WOOD labels are not usually used since the program will compute them if they are not entered. Once all the labels have been entered that you wish to set, enter a WRITE to make the changes permanent. The program will then request the next station number to be modified. If the task is complete, enter a carriage return. This returns the user to AFFIRMS. See the following example:

```
COMMAND:LINK COFMOD$C
**AFFIRMS ANCILLARY ROUTINES:  CARRY-OVER FUELS MODS
STATION ID?041095

FIELD (THOU,HUND,STAGE,HERB,X1000,WOOD,WRITE)? X1000

x1000 VALUE FOR MODEL A4A?20.5  (two requests since there are
x1000 VALUE FOR MODEL B3A?12.5   two models in this catalog)

FIELD (THOU,HUND,STAGE,HERB,x1000,WOOD,WRITE)?WRITE

RECORD 51 UPDATED

STATION ID?     (carriage return)

COMMAND:
```

4.3.4 Modifying Manning Index Percentiles--The LINK MIBKOV$C Command

The LINK MIBKOV$C command calls an ancillary routine which can modify the 90th and 97th percentiles for the model-slope-grass type combintation that were specified with the MODL command. By avoiding the reentry of the MODL command the operations discussed in Section 4.4. can be avoided.

The routine will request a station number and then give the user three labels to choose as inputs. The first two, (MI90,MI90), select either the 90th or 97th percentile as the target of the change. The last one (WRITE) makes any previous change permanent. After a "WRITE" has been entered the routine requests another station number. If a carriage return is entered without a station number the routine returns control to AFFIRMS. Several agencies use percentiles other than the 90th-97th. If this is the case, interpret the 90th and 97th as the low and the higher one, respectively. See the followin example:

```
COMMAND:LINK MIBKOV$C

**AFFIRMS ANCILLARY ROUTINES: M.C. BREAKPOINT OVERRIDE
STATION ID?041095

FIELD (MI90,MI97,WRITE)? MI90

NEW VALUE OF MI90 FOR MODEL A4A?50

NEW VALUE OF MI90 FFOR MODEL B3A?60

FIELD (MI90,MI97,WRITE)?WRITE

RECORD 2133 FOR STATION 41095 UPDATED

STATION ID?  (Carriage return)

COMMAND:
```

APPENDIXES

APPENDIX A

Examples of Typical Sessions with AFFIRMS

After you have signed on to AFFIRMS (Section 1.4.1), the program will cause a prompter, the word COMMAND: to be printed on your terminal. The program is then ready for your first instruction. Usually, if the command is successful, you will receive no message. If anything is wrong, you will receive a message which briefly describes the problem. If you need further help, the error-codes manual will give a more complete explanation (appendix C).

As soon as AFFIRMS has responded to your command, it will prompt you to enter a new command. This procedure goes on until you are through and wish to end the session. At this point, the BYE command will disconnect you from the computer.

Let us look at a typical AFFIRMS session as it might be conducted at a Forest Supervisor's Office. Comments have been placed at the end of some commands to describe their function.

he fire weather observations were entered, then the fire indexes for those bservations were displayed. At that time, additional display commands could have een typed to ask for weather and/or indexes for surrounding wildland areas--perhaps rom the next Forest.

```
HH U#=MAN68519,WHIZBANG,SMITH


NFDR '78 AFFIRMS (328/28/8/3) FOR ASSISTANCE, CALL FTS 554-9458 OR COM (208)

384-9455


     COMMAND:OBS 015392 14 0 85 52 1 100 5 14 4 86 43 M  M 0 0 1 59
     COMMAND:OBS 015393 14 0 78 54 1 100 4 6 3 80 45 M  M 0 0 1 50
     COMMAND:OBS 015394 14 0 76 51 1 100 5 9 5 76 47 M  M 0 0 1 50
     COMMAND:OBS 015395 14 0 71 47 1 100 6 12 5 76 53 M  M 0 0 1 50
     COMMAND:OBS 015396 14 0 67 44 1 100 8 8 6 68 36 M  M 0 0 1 50
     COMMAND:OBS 015397 14 0 54 29 1 100 3 12 4 54 36 M  M 0 0 1 50
     COMMAND:OBS 015398 14 0 69 48 1 100 2 7 5 80 35 M  M 0 0 1 50

COMMAND: DSPX OBS SIG 028

----------------03/27/79--OBS---19:47GMT---------------
STAT'N MSGC DY HR TH IC LR LO MR MO  SC  EC  BI FL MC R
015392 D1P3 27 14 20 92  0  0 99 91  58  60 128 99  5 E
015393 O1P3 27 14 23 43  0  0 99 43  28  63  94 73  5 V
015394 P1P3 27 14 23 57  0  0 99 56   7  33  37 48  5 V
015395 N1P3 27 14 23 64  0  0 99 63  99  27 114 92  5 V
015396 O1P3 27 14 23 51  0  0 99 50  38  57 104 82 5 V
015397 N1P4 27 14 28 77  0  0 99 76  99  29 118 99 5 E
015398 P1P3 27 14 24 45  0  0 99 45   5  32  32 39 5 V

COMMAND:BYE


(TSP) COST: $  3.17

00049.36  CRU   0000.13 TCH    0001.69 KC


OFF AT 12:48 MST 03/27/79
```

ese same observations were displayed by the fire weather forecaster using the DSPW S command. The forecaster then prepared two types of forecast: 1) a narrative orecast in plain language, which the forecaster stored using a specific text file me (the letters FWX plus the three-letter airport code, for example, "FWXLAX" for s Angeles), and 2) a numerical trend forecast for each fire weather zone using the NE command.

te in the afternoon, the Forest Supervisor's office again called the computer and quested a display of the forecasted weather and indices plus a listing of the rrative forecast. Finally the DSPU command was used to get a weighted average orecasted fire danger for the Forest.

```
    HH
    U#=MAN68519,WHIZBANG,SMITH
    NFDR '78 AFFIRMS (328/28/8/3)


    FOR ASSISTANCE, CALL FTS 554-9458 OR COM (208) 384-9455


OMMAND:FILE LIST FWXBHM

LABAMA FIRE WEATHER "FORECAST...9AM C,ST TUE, MAR 27, 1979
AT'L WEATHER SERVICE FORECAST OFFICE...B'HAM, AL

YNOPSIS...HIGH PRESSURE WAS CENTERED OVER SOUTH ALA AND A WEAK
OW PRESSURE AREA WAS OVER EAST OKLA THIS MORNING.
 GRADUAL INCREASE IN SOUTHEAST TO SOUTH WINDS WILL OCCUR OVER
LA THRU WEDNESDAY AS THE HIGH MOVES TO THE ATLANTIC COAST.
THERE IS A RISK OF SHOWERS OVER NORTHWEST ALA AS WINDS
INCREASE BUT PROBABILITIES ARE LESS THAN 20 PERCENT."
```

```
                                    TODAY                   WEDNESDAY
                              NORTH    SOUTH          NORTH          SOUTH
SSS
SKY CONDITION                 P.CLDY   M.CLEAR        P.CLDY
PRECIPITATION (TYPE)          NONE                    NONE
HIGH TEMPERATURE              68-73    73-76          73-75    75-77
WIND (MPH)                    SE 5-8   SE 4-6         S 6-12   GUSTY
MIN. REL. HUMIDITY            30-35%                  40-45%
MIXING HEIGHT (AFTN)          4,000    5,000          4,500    5,000
3,000 FT. WIND (MPH)          SW 20    S 12           SW 35    SW 25
VISIBILITY (AFTERNOON)        7 MI                    7 MI
ATMOSPHERIC STABILITY         NEUTRAL                 NEUTRAL
STAGNATION INDEX              8-10     9-11           0-2      1-3

TONIGHT...P.CLDY.  TEMPS 40S N & 50S SOUTH.  WINDS SE 4-8 MPH.
RH 90-95%.  STAG INDEX 3-6.  NEUTRAL BECOMING STABLE LATE.


END SENT 8:55AM CST ...JWW

---

COMMAND:SET NAMES ON


COMMAND:DSPI FCST ZONE 802 8




------------------------03/27/79--FCST--20:02GMT---------------------
STAT'N MGSC DY WS WDY HRB 1H 10 HU TH IC LR LO MR MO SC EC BI FL MC P

HOLLY  E3P3 27  3  70  10 10 19 16 20 11  0  0  2  0  6 14 22 16  3 M
FANNIN R2P3 27  2  70   7  7 12 29 48 16  0  0 17  3  1 10  9  7  3 M
BRASS  E3P3 27  4  70  11 11 22 11 17  7  0  0  2  0  6 12 22 16  2 L
TALLAH E3P3 27  6  70   9  9 13 26 34 15  0  0  2  0  8 15 28 20  3 M
LUFTEE E2P3 27  3  70  10 10 17 23 25  8  0  0  4  0  4 13 18 13  3 M
COVE   E2P3 27  2  70  12 12 32 25 27  4  0  0  7  0  3  8 13  9  2 L
GATBRG E2P3 27  2  70   9  9 15 24 29 10  0  0  7  1  3 15 18 13  3 M

COMMAND:BYE

(TSP) COST:$1.19
00015.35  CRU      0000.06 TCH     0002.82 KC

OFF AT 13:02MST 03/27/79
```

APPENDIX B

Common Errors

		Reference
1.	The exact format must be used in the sign-on procedure. This requires the identification number, comma, password, comma, operator's name or initials, carriage return. Spaces are not permitted.	1.4.1
2.	Use the proper error correction method. The back space procedure (commonly a back arrow or a shift underline) to enter corrected data; the "control X" to delete an entire line; and the "break" key to stop the printing and execution of an unwanted operation.	1.3.1 1.4.4
3.	Station catalogs should not be deleted at the end of each season. It is cheaper to leave the stations cataloged. The cost of storing the catalog is very small and is included as part of the AFFIRMS overhead charges.	2.1.8 fire
4.	Error messages should be read and the expanded explanation looked up in appendix C. Remember, the letter at the end of the message number will tell you if the message is for information (I) and if the command has been accepted; for action (A) and the command rejected; or for referral (R) to the AFFIRMS staff for corrective action.	APP. I
5.	A space is not permitted between the prompter (COMMAND:) and your command.	1.2

6. If an entire entry has been left out of an OBS command, the message up arrow ( ) may not show the exact location of the error. (For example, if the wet-bulb temperature has been left out, the error message might be that a letter entry (for wind direction) was found in a field reserved for numerals and the arrow indicates the man-caused risk field.) 2.2.1 erro

7. When entering observations, a minus sign should be entered with the precipitation duration if the fuels were wet or covered with snow or ice at observation time. This causes all indexes to revert to zero. 2.2.1

8. When entering observations, use a "T" for a trace of rain (less than 0.005 inches). 2.2.1

9. The UNIT designation on the display command costs about three times as much as LIST or ID designations. The SIG command is inefficient for less than five stations. 1.5.1

10. Use SET DAYS -1 command before making DSPU FCST commands for tomorrow's forecasted weather. The SET DAYS -1 command is not used if you are making a DSPU FCST command in the morning to cover the rest of the same day. 1.5

11. The break-key terminates the FILE MAKE operation. Be sure to use a carriage return to enter the last line of text into the file before the break-key is depressed. 1.7.1

12. Use a FILE LIST command to view the contents of a file. The FILE LIST is used for fire weather narratives, etc. The FILE READ command tells the computer to execute the commands in the file in the same order they are entered. 1.7

13. The name of a file cannot contain a space, it must begin with a letter and must end with the last three digits of your user-number. 1.7.6

14. Storage costs for most files are $0.63 per month per file. Purge old files when they are no longer needed. 1.7.6

15. Check to be sure a POST command has been completed before purging the file. 1.8.3

16. Be very careful in using FILE READ commands within files. A loop may result where File A instructs the computer to read File B which tells the machine to read File A. Computer costs (which you pay) can mount very quickly from this error. Use the break-key to stop an undesired action, and a FILE LIST to view the contents of a file to determine the source of errors. 1.7.3

17. A MODL command erases the herbaceous and woody vegetative conditions, as well as deleting the computed 1000HR and x1000 moistures. The COFMOD$C program (See 4.3.3) might be needed after entering a new MODL command. 2.1.4, 2.1.5, 2.1.6

APPENDIX C

Explanation of AFFIRMS Messages

All AFFIRMS messages consist of two parts: a brief message preceded by a code--three letters, two digits, and a suffix lettter. The suffix letter indicates the kind of message:

A	ACTION--The indicated error must be corrected by the terminal operator.
I	INFORMATION--A warning, perhaps nothing is wrong, entry accepted.
R	SERIOUS PROBLEM--Report to system staff immediately!

The following telephone numbers may be used to report SERIOUS PROBLEMS (R) with AFFIRMS. Please use the numbers in the order given:

Regular Hours	Commercial	208-334-9458
Regular Hours	FTS	554-9458

* * * * *

ALF01A NON-ALPHABETIC CHARACTER IN ALPHA OPERAND

A character other than A thru Z or (-) was found in an operand which AFFIRMS expects to be alphabetic. The up-arrow points to the defective operand.

ALF02A IMPROPER LENGTH (OVER 4 CHARACTERS)

AFFIRMS has found more than four characters in an operand which was expected to be alphabetic (or mixed).

COMMAND: Normal program prompter. Enter your next request.

CFP02R C.O.F. DIRECTORY FULL, ENTRY NOT STORED

The current observation file was found to be full. Report immediately to AFFIRMS staff since the file for the Region must be expanded or no new data can be recorded.

CTL01R CAT-DIRECTORY I/L FAILURE

The catalog-directory indicates that a given station is cataloged, but the corresponding record in the catalog does not refer to that station. Report to AFFIRMS staff for corrective action.

CTL02A INVALID STATION NUMBER

In a catalog-maintenance command, the station-number given is not six digits long.

CTL03A STATION NOT IN CATALOG

A request to delete, describe, or modify a catalog entry was entered f station not previously cataloged, or one that has already been deleted.

CTL04A IMPROPER LENGTH

An operand has the wrong number of digits or letters. Refer to manual sections on CTLG, HDEF, OPT, MODL, HERB, NAME, or WOOD commands, as appropriate.

CTL05A INVALID TIME-ZONE

Time-zone must be entered as EST, CST, MST, or PST only in the Contine United States. HST should be used for Hawaii and most of Alaska. Us BST for far western Alaska and YST for the small part of Eastern Alask not in Hawaiian time.

CTL06A INVALID STANDARD OBS-TIME

Standard-Observation-Time must be entered as a two-digit number betwee and 24.

CTL07A Not Assigned

CTL08A MODEL OPERANDS NOT IN PAIRS

Following the STATION-I.D. and CLIMATE CLASS in the MODL command, the operands must be entered in sets of two (MODEL-SLOPE-GRASS TYPE, MI97-MI90), one set for each model to be specified. Up to four sets permitted.

CTL09A INVALID MOISTURE-ENTRY-CODE

In the HDEF command, the moisture-entry-code must be entered as a one-digit number from one to six only.

CTL10R CAT.-DIRECTORY I/L FAILURE

See CTL01R for explanation.

CTL11A INVALID SLOPE-CLASS

SLOPE-CLASS must be entered as a one-digit number, 1 through 5 only.

CTL12I CATALOG SUBSTITUTION

A station with the same number as the one being cataloged already exists in the catalog. The new entry overrides the old one. Warning: After the CTLG command has caused this substitution the MODL, HDEF, OPT, HERB, and WOOD commands must be entered to make the catalog entry complete. The old values are not retained. Also the 100, 1000, and x1000 moistures have been lost. See Section 2.1.1.

CTL13A INVALID REGION-NUMBER

REGION-NUMBER must be a one- or two-digit number from 1 to 10 only.

CTTL16A ELEVATION NEGATIVE, OR IMPOSSIBLE FOR U.S.A.

STATION-ELEVATION must be a positive number from 0 to 20300 feet MSL.

CTL17A OPERANDS NOT IN MODEL-AND-VALUE PAIRS

In an HERB command, a model identifier was given without a data value after it or vice-versa.

CTL18A MODEL NOT CATALOGED FOR THIS STATION

In an HERB command, a model identifier was specified that had not previously been cataloged for the station with a MODL command.

CTL19A INVALID HERBACEOUS STAGE CODE

In an HERB command, a condition value was specified other than GREEN, CURED, or FROZEN.

CTL20A INVALID WOODY FUEL MOISTURE

In a WOOD command, a value was specified outside the range 50 to 200.

CTL21A INVALID NUMBER OF DISPLAY CLASSES

In an OPT command, the number of Manning-Classes was not between three and nine.

CTL22R STATION DOES NOT BELONG TO USER

Once a station has been cataloged, only the user who originally cataloged it may make modifications to the catalog entry. If you wish particular station moved to your jurisdition, and the original catalogi user agrees, have that user delete the station from the catalog with a command. Then catalog it yourself, under your user-number. This secu check is designed to protect your station catalog entries from unauthorized tampering. All stored fuel moistures will be lost. See Section 2.1.

CTL23A INVALID MANNING-INDEX SPECIFICATION

Manning-index must be specified as IC, SC, EC, LO, MO, LR, BI, or FL o If the operand is entered as missing (M), BI is used by default.

CTL24A Not Assigned

CTL25A INVALID PERENNIAL/ANNUAL CODE

Grass-type must be specified in a MODL command by letter 'A' or 'P' or

CTL26A INVALID CLIMATE CLASS

Climate class must be a one-digit number from one to four only.

CTL27A INVALID LATITUDE

CTL28A INVALID LONGITUDE

Valid entries in the LOC command are latitude from 18.7 to 75 degrees longitudes from 65 to 170 degrees. Note that these are decimals of degrees, not minutes, after the decimal point.

CTL29A INVALID OR FUTURE 'NEW-STICK' DATE

Date of new-stick installation should be entered in the form YYMMDD (example, July 27, 1978 is entered 780728).

CTL30A INVALID LIGHTNING SCALE FACTOR

The valid range is 0.01 to 5.00.

CTL31I 'CURED' INVALID WITHOUT PRIOR GREENUP, SET TO 'PREGREEN'

A declaration of "GREEN" entered with the HERB command, must precede declaration of "CURED".

CTL33I WARNING: STATION CATALOGED OUTSIDE ITS ACTUAL REGION

During cataloging, it is possible to specify a Region-Number (in the 'CTLG' command) that does not normally contain the State in which the station is located. This sometimes needs to be done because a station is operated by a user who is located across a Regional boundary from the station. The Regional specification tells AFFIRMS where to store the data for that station. The only scope that will work in the display commands (see Section 1.5) are Region and Zone.

CTP01R CATALOG DIRECTORY FULL, ENTRY NOT STORED

A station has been entered for cataloging but the catalog is already full. Report to AFFIRMS staff since the catalog must be expanded before any new stations can be cataloged.

CTP06R STATION DOES NOT BELONG TO USER

See CTL22R for explanation.

DFC01A NON-NUMERIC CHARACTER

In an operand expected to contain only a numeric value, a character other than 0 thru 9, +, - and decimal point has been found. The up-arrow indicates the defective character.

DFC02A IMPROPER SEQUENCE

In a numeric operand, one of the following errors has occured: + after +, + after -, - after -, - after +, - or + after digit, more than one decimal point, or + or - after decimal point. The up-arrow indicates the defective character.

DFC03A DEC. PT. IN INTEGER FIELD

In a numeric operand, a decimal point was found that was not legal for the operand in question.

OP01I BUSY (SHARED OPEN), STANDBY:xx

OP02I BUSY (SHARED LOCK), STANDBY:xx

DOP03I BUSY (SHARED UNLOCK),STANDBY:xx

While attempting to access a random-access community data file (C.O.F., catalog, etc.) the file was found to be busy (another user of AFFIRMS wa writing in it). Your execution is suspended for 3 seconds and another t is made. The message will be repeated every fifth try if necessary. If the message occurs many times, you may escape the loop by hitting break return to the COMMAND: point.

DSP01A WRONG NUMBER OF OPERANDS

Too few or too many operands were given for a display.

DSP02A INVALID SCOPE

In a display command, the second operand was not recognized. Use only RE UNIT, ID, STAT, CNTY, SIG, ZONE, or LIST.

DSP03A IMPROPER LENGTH

The operand pointed to by the up-arrow has the wrong number of digits o letters.

DSP05A INVALID REGION-NUMBER

The REGION-NUMBER given was not a one- or two-digit number between one ten.

DSP06A BOTH STATION NUMBERS ARE MISSING

In a display command with ID scope at least one station number must be given. The other, being missing, may be defaulted. If the first is defaulted, it is treated as 010101. If the second is defaulted, it is treated as 509999.

DSP08A INVALID STATE-CODE

STATE-CODE must be a two-digit number between 01 and 50.

DSP09A INVALID COUNTY-CODE

COUNTY-CODE must be a four-digit number between 0101 and 5099.

DSP10A INVALID FOREST-CODE

UNIT NAME must be given as a four-letter code.

P11A IMPROPER STATION I.D.

Station I.D. must be a six-digit number between 010101 and 509999.

P12I NO DATA MEET YOUR CRITERIA

In a display command, no data currently in the files meet the specifications given in the command. Your SET DAYS specification may be wrong. If a SET command is not in effect, the stations requested do not have OBS for today or forecasts for tomorrow.

P14A S.I.G. NUMBER OUT OF RANGE

In a display command with SIG scope, the number of the special interest group is incorrect. Numbers must be a three-digit number between 001 and 350. Check with AFFIRMS staff.

P15A INVALID TYPE-QUALIFIER

In the display command, only OBS, SPC, or FCST are allowed as qualifiers.

P16A INVALID WEIGHTING FACTOR

Weighting factor must be a number between 1 and 99 percent.

P17A INVALID SLOPE-CLASS SPECIFICATION

See CTL11A.

P18A SUM OF WEIGHTING FACTORS IS NOT 100 PERCENT

In a DSPU command, the weighting factors must sum to 100 percent.

P19I NO DATA ON SELECTED DATE FOR STATION:xxxxxx

In response to a DSPU command, AFFIRMS could not locate data for the indicated station with the current SET DAYS specification. There may be data available for the station, but not of the specified age!

P20I MODEL/SLOPE NOT AVAILABLE IN DATA FOR STATION:xxxxxx

In response to a DSPU command, AFFIRMS found data for the specified station, but the model-slope combination specified in the command could not be found in the data. Check the station catalog entry by using the DESC command.

P21A NO DATA AVAILABLE FOR UNIT

AFFIRMS could find no data (given the current SET DAYS specification) for any of the stations in a DSPU command.

EXC02A IMPROPER OR FUTURE DATE

In a DATE command, the fields must be entered in the order YEAR-MONTH-D and the combination must be legitimate. Fields must be entered as two digits each.

EXC03A COMMAND NOT LEGAL AFTER 'DATE'

Once a DATE command is in effect, certain commands cannot be entered ur the date has been turned back by hitting "BREAK." See Section 1.4.6.

EXC04I DATE OVERRIDDEN YY/MM/DD

The DATE command just entered will remain in effect until the break-ke hit or another DATE command is entered. This message will be printed after every command, except ARCH, entered from the keyboard to remind operator that the date has been changed.

EXC05A OPERANDS NOT IN PAIRS

The number of operands in a SET command must be even.

EXC06I MSG 'xxxxxx' FROM USER NO. xxx DATED xxxxxx:

Precedes posted message; contains name of file, the user number of the originator, and the date it was posted.

EXC08I FILE-MODE CANCELLED

The Break-Key was hit when AFFIRMS was reading its commands from a specified text file. The processing of the file ceases, and the term goes back to keyboard mode.

EXC09I DATE REVERTED

The break-key on the terminal was hit while a DATE command was in eff causing the current date to be reinstated.

EXC10A INVALID OPERATION

The set command allows 16 operations: ECHO, HEAD, DAYS, MEDIAN, MEAN, NAME, AC, MC, DWPT, BREAK, LINES, WAIT, THOU, and TAPE.

EXC12A INVALID DISPLAY-RANGE

The SET DAYS command permits range from -1 to 31 days only.

EXC17A INVALID MANNING-CLASS 'FLOOR', ZERO USED

In a SET MC command, the manning class 'floor' must be specified as: 0,1-,1+,2-,2+,3-,3+,4-,4+,5.

EXC18A INVALID ADJECTIVE-CLASS "FLOOR," ZERO USED

In a SET AC command, the adjective class 'floor' must be specified as: 0, L, M, H, V, or E only.

EXC21A 'DATE' MUST PRECEDE 'ARCH' (EVEN FOR TODAY)

A DATE command must always be used before ARCH to ensure proper archiving.

EXC22R CONTACT AFFIRMS STAFF! ARCHIVER FAILED, LAST DATE:xxxxxx

The AFFIRMS archiver program has apparently not completed work properly on a previous night. Call BOISE or RIVERSIDE at once!

EXC23A INVALID DISPLAY-LINES SPECIFICATION

The SET LINES command allows from one to four lines to be specified.

EXC25A INVALID DEFAULT MOISTURE SPECIFICATIONS

The SET THOU command allows entries from 2 to 200 percent.

EXC26A 'ARCH' COMMAND INVALID FOR PSEUDO-STATIONS

The ARCH command provides for direct archiving of data for regular Fire Danger Rating stations. Pseudostations for prescribed burning or research cannot have their data archived.

EXC331I REMINDER! NAMES OF CURRENTLY-SAVED FILES ARE LISTED BELOW, FOLLOWED BY LAST-DATE-ACCESSED.

This message precedes the listing of saved file names produced on Mondays by the command BYE.

FIL01A INVALID OPERATION

The FILE command permits only the READ, MAKE, LIST, NAMES, COPY, and PRGE operations.

FIL02I NOW EXECUTING FILE 'XXXXXX'

A FILE READ command preceded, and AFFIRMS is taking its commands from the specified file. The keyboard is not connected to AFFIRMS and commands should not be entered until the END-OF-FILE ENCOUNTERED message is received. (This does not preclude use of the break-key to escape back to terminal-mode). If AFFIRMS takes an inordinate amount of time to respond to the commands in the file, you can check on your status by typing STATU followed by carriage-return. The computer system will type RUN if you ar still connected to the computer and AFFIRMS is still running.

FIL03R SEQUENTIAL FILE READ-ERROR, CODE: xx

After a FILE LIST command was entered, a machine failure occured, retry the command; if the problem persists, contact the AFFIRMS staff.

FIL04R 'CREATE' FAILED (PROBABLY IMPROPER FILE-NAME), CODE: xx

A machine failure occured when setting up a new file. Contact AFFIRMS staff if the errors persist after using another file name and verifying that the file name meets the requirements in 1.7.1.

FIL05I EXISTING FILE. DO YOU WANT TO OVERWRITE (YES/NO)?

A FILE MAKE command specified the name of a file that has been previousl created and is still stored. If you answer NO, the command is bypassed. If you answer YES, the file is re-created, empty, and ready for new text

FIL07A PURGE FAILED (MAYBE NOT YOUR FILE), CODE: xx

A FILE PRGE (or FILE MAKE for an existing file) was unsuccessful, either because of a system error, or because the named file belonged to another user, or because another user was doing a FILE LIST or FILE READ on your file. Check with AFFIRMS staff.

FIL08R 'PERMIT' FAILED (TRY A DIFFERENT FILE-NAME), CODE: xx

A FILE MAKE command specified the name of a file already stored by anoth AFFIRMS user.

FIL10R 'DSM' FAILED, CODES: XX/XX

A system failure prevented your entered text from being stored in the named file. Contact AFFIRMS staff.

FIL11I HIT "RETURN" THEN "BREAK" AFTER LAST LINE OF TEXT READY FOR INPUT

AFFIRMS is storing your text directly in a file. It will not respond to any typed entry until after the break is hit to indicate that the file creation is complete.

FIL12R PRELIM. PURGE FAILED, (PROBABLY NOT YOUR FILE), CODE:xx

See FIL07A for explanation.

FIL13A LAST 3 CHARACTERS OF FILE NAME AND USER NUMBER DON'T MATCH.

All user file names must end with the last three digits of the user number under which the current session is being conducted. This will prevent identical file names being created by different users. It also makes it easier for AFFIRMS staff to trace files to the originator. The one exception to this rule is the names assigned to text files containing the weather forecast narrative--those must begin with FWX.

INT01A WRONG NUMBER OF OPERANDS

The number of operands given is either too few or too many for the kind of special interest group operation being performed.

SIG nnn,ADD;	Requires at least three
SIG nnn,DEL;	Requires at least three
SIG nnn,LIST;	Requires only two
SIG nnn,CLR;	Requires only two

INT02A IMPROPER STATION I.D.

See DSP11A.

INT03A INVALID OPERATION

The SIG command allows only the ADD, DEL, LIST, and CLR operations.

INT04I GROUP EMPTY

The special interest group specified contains no station-numbers. Either none have been added or all have been deleted previously.

INT05A GROUP FULL

The specified special interest group already has 20 station-numbers and no more can be added. If the group became full during an ADD operation. The up-arrow will point to the first station ***not*** added to the group. Those appearing to the left of the arrow were successfully added.

INT06A S.I.G. NUMBER INVALID

The I.D. of a special interest group must be a three-digit number.

INT07A S.I.G. BELONGS TO ANOTHER USER

Another AFFIRMS user has already placed station numbers in the special interest group which you have tried to modify. Use SIG 999,LIST to loca a free group.

INT08A I/O ERROR IN S.I.G. FILE, RE-TRY COMMAND

During processing of a SIG command, the interest-definition file could n be accessed because of a machine failure. Try the command again. Repor to AFFIRMS staff if the problem persists.

INT09I GROUP UNASSIGNED

The cited S.I.G. is not currently assigned to any user.

INT10R ALL GROUPS ASSIGNED, NONE AVAILABLE

Contact AFFIRMS staff immediately!

INT11I AVAILABLE GROUP:XXX

In response to SIG 999,LIST AFFIRMS supplies the number of a special interest group currently 'free' and available for your use.

INT12I USER NUM:xxx LAST MOD:xx/xx GROUP CONTAINS STATION(S):

This message is the response to a SIG nnn LIST command. AFFIRMS indica the 'owning' user's number, the month-and-year when last used (that is, the last time a display command with SIG scope referenced this group), the station numbers currently in the group.

LST01A IMPROPER QUALIFIER

A STOW command was entered which specified neither ZONE or ID.

LST02I LIST NOW STOWED

A STOW command was successfully processed.

LST03A IMPROPER STATION I.D.

Similar to DSP11A.

ST04A IMPROPER FIRE WEATHER ZONE NUMBER

Similar to ZON11A.

DS01A MODEL (X) NOT RECOGNIZED

The specified MODEL-NAME is not legal. The MODEL-NAME must be a single alphabetic character between A and U only.

BP01A STATION NOT IN CATALOG

The specified station has not been previously cataloged, nor has it been deleted.

BP02A INVALID OBS-TIME

OBSERVATION-TIME must be a two-digit number between 01 and 24.

BP03A INVALID STATE-OF-WEATHER CODE

STATE-OF-WEATHER must be entered as a one-digit number between 0 and 9 only.

BP04A INVALID TEMPERATURE

DRY-BULB-TEMPERATURE must lie within the limits -100 to +136. A decimal point may be included.

BP05A STATION HAS UNDEFINED -HDEF-

A HDEF command has never been used for this station, or was not given after the station was recataloged. Since no specification has been given, AFFIRMS has no way of knowing whether the humidity data in OBS or SPC commands is relative humidity, wet-bulb temperature, or dewpoint. Use the HDEF command to make the proper specification, and to reenter the observation.

BP06A IMPROPER WET-BULB, DEWPOINT, OR REL.-HUM. ENTRY

The relative huumidity, either observed or computed by using the DEWPOINT or WET-BULB, has been found to exceed 100 percent or is less than 1 percent.

BP07A NOT ASSIGNED

OBP08A INVALID MAN-RISK OR LIGHTNING ACTIVITY LEVEL

RISK-LEVEL must be entered as a one- to three-digit number between 0 ar 100 only; lightning-activity must be entered as a one-digit number betw 1 and 6.

OBP09A INVALID WIND DIR.

WIND DIRECTION can be entered in any of the four systems in common use--16-point-letter code (NE,S,SE,SSW,etc.), 16-point-number code (01 NNE, 08 for South, 16 for North, etc.) eight-point-number code (1 for 8 for N, etc.), or degrees-of-the-compass (023,180, 270,etc.). The da are self-identifying if properly entered. Remember that degrees-of-the-compass must always be 3 digits (use zeros as needed). Sixteen-point number code must always be two digits (use a leading zer for values between 1 and 9).

OBP10A INVALID WINDSPEED

WINDSPEED must be entered as a one- or two-digit number from 0 to 99 only.

OBP11A NOT ASSIGNED

OBP12A INVALID 10-HR-T/L FUEL MOISTURE

The fuel stick moisture content must be a number between 0 and 99. A decimal point is allowed (example 12.5).

OBP13I INCONSISTENT MAX. TEMP. OBSERVED TEMP. USED: xxx

The MAXIMUM TEMPERATURE entered must be equal to or greater than the OBSERVED TEMPERATURE, and must lie between -100 and +136. If the ente value violates these limits, the observation time temperature is used replace the maximum temperature.

OBP14I INCONSISTENT MIN. TEMP., OBSERVED TEMP. USED: xxx

The MINIMUM TEMPERATURE entered must be equal to or less than the OBS TEMPERATURE, and must lie between -100 and +136. If the entered valu violates these limits, the observation time temperature is used to re the minimum temperature.

OBP15I INCONSISTENT MAX. HUMIDITY, OBSERVED HUM. USED: xxx

Similar to OBP13I except limits are 1 and 100 percent.

OBP16I	INCONSISTENT MIN. HUMIDITY, OBSERVED HUM. USED: xxx	Similar to OBP14I except limits are 1 and 100 percent.
OBP17A	INVALID PRECIP. DURATION(S)	PRECIP. DURATIONS are limited to 16 and 8 hours, respectively, and their sum must be 24 or less.
OBP18A	'MAKE THEE AN ARK, GATHER THE ANIMALS 2 BY 2 ...'	24-hour PRECIPITATION AMOUNT must be between 0 and 9.99 inches. A decimal point is required; for example, .12 for twelve-hundredths.
OBP19A	INVALID LIGHTNING REPORT	LIGHTNING ACTIVITY LEVEL must be reported as a one-digit number from one to six only.
OBP22A	MISSING MOISTURE VARIABLE	RELATIVE-HUMIDITY, DEWPOINT, or WET-BULB-TEMPERATURE (depending on the HDEF specifications for the station) is required data and must not be entered as missing.
OBP27I	WRONG NUMBER OF OPERANDS	OBS commands must have 18 or 19 operands, FCST commands must have 16, and SPC commands must have 17.
OBP31R	STATION DOES NOT BELONG TO USER	An OBS command has been entered by a user other than the one who originally cataloged the station involved. If you wish to enter data for this station, and the user who owns the station agrees, have him delete the station; then catalog it under your user number, also check for a typographical error in the station number.
OBP33A	"OBS" TIME MUST BE WITHIN 2 HOURS OF XXXX	For OBS or ARCH commands, the time of observation must be within 2 hours of the STANDARD OBS TIME specified in the station catalog.
OBP34A	STOW CONTAINS NO STATION-NUMBERS	Similar to ZON08A, but issued for FCST command.

OBP35I UNUSUALLY LOW STICK MOISTURE (UNDER 2.0) ACCEPTED, BUT PLEASE CHECK CALIBRATION OF SCALES AND STICKS

Stick moistures under 2 percent are very uncommon. Although AFFIRMS wil accept such values, it is wise to recheck the calibration of your system for possible defects.

OBP36I NO RECENT OBS, "OLD" 10/100-HR F.M. TAKEN AS: XX/XX

Whenever an OBS command is entered, AFFIRMS fetches the last observation for the station and obtains the 10-HR and 100-HR moistures. These are used in computing "today's" values. If no 'last' OBS could be found les than 4 days old, AFFIRMS assumes default values for each.

OBP37A NEW OBS NOT PROCESSED, PRE-DATES LAST OBS (DATED:xxxxxx)

An OBS command may be used with DATE to enter several days of stale data usually to properly trend the 100-HR and 1000-HR fuel moistures. Such stale OBS must be entered IN ORDER, begining with the oldest first.

OBP38A NON-ZERO PRECIP. AMOUNT MUST HAVE DECIMAL POINT

To reduce entry errors AFFIRMS requires that the decimal point be inclu unless the precipitation amount is zero. For example 32 hundredths mus be entered as 0.32 or as .32.

OBP39A PRECIP. DURATION INCONSISTENT WITH PRECIP. AMOUNT

If precipitation duration is entered as zero then logically precipitati amount must be zero as well. On the other hand, if either is entered a real value then both must be greater than zero.

OBP40I NO FCST LAL AVAILABLE, USED OBS. MORNING LAL: X

Today's lightning risk is computed using yesterday's LAL and the highes of today's observed LAL (ML) or the LAL forecasted for today. When a forecasted LAL is not available for today, the morning LAL is used.

OBP43I FREEZE DETECTED. "HERB" COMMAND SPECIFYING FREEZE-UP MAY BE NEEDED FOR THE FOLLOWING FUEL MODEL(S):

MODEL: A, SLOPECLASS: 4 MODEL: B, SLOPECLASS: 3

A minimum temperature below 32°F has been noted in the OBS. If this temperature killed the herbaceous vegetation at your station and force the woody vegetation into dormancy, then enter a HERB command of "FROZ If only the herbaceous vegetation was effected, enter a HERB command o "CURED". If there were no effects, then ignore this message.

BP44A MAX/MIN TEMP/HUM CANNOT BE MISSING IN THE 'FCST'

These items must be specified in the FCST; they are optional in OBS.

BP49R OLD OBS 'STALED' (BAD DATE or ALTERED CAT.); DATES: xxxxxx
and
BP50R COF/DIR I/L FAILURE, TREATED AS "STALE"; ID/REC:

Both of these messages arise from severe program problems. The station is run through season initialization to recover. Report to the Staff at once!

BP51I SEASON INITIALIZATION; X1000 & 1000-HR SET TO: XXX

The station has no old OBS within the preceding 50 days; so processing proceeds as if the station were starting the season from scratch.

BP52I WOOD FM COMPUTED (LAST MEASURE STALE, DATED: XXX)

A WOOD command was entered previously but the measurement is between 30 and 35 days old. A new measurement should be made. Until a new WOOD command is entered, the program will compute the woody moisture content. The message is suppressed after 35 days.

K MORE: Normal prompter in response to an "&" in the previous line. Continue to enter the command begun on the preceding line.

PN01I SEQUENTIAL FILE BUSY, STANDBY

A text file was in use by another user when AFFIRMS tried to access it for you. AFFIRMS keeps trying every 3 seconds; the message is printed every 15 seconds (every fifth try). If you wish to abandon the task, you can hit break. The work specified in your last command, however, will not be performed.

PN02R SEQUENTIAL FILE OPEN-FAILURE, CODE: xx

A machine failure prevented access to a text-file. Please report the code number to AFFIRMS staff.

PN03I SEQUENTIAL FILE 'xxxxxx' NOT SAVED

A FILE command was entered, specifying an "existing" file which could not be found in the library.

PR01R UNEXPECTED END OF BUFFER

This is a theoretically impossible condition. Report to AFFIRMS staff, along with the command which produced it.

PST01I FILE NOT CURRENTLY POSTED

A POST command with only a file name (treated as a DEPOST) specified a file not currently cited in the route-file.

PST02R I/O ERROR IN ROUTE FILE, RE-TRY COMMAND

A machine failure prevented a POST command from being entered into the route-file. Try the command again; if the error persists, contact AFFI staff.

PST03I REQUEST SERVICED

Processing of a POST command terminated normally.

PST04A INVALID USER-NUMBER

USER-NUMBERS must be three digits long, from 001 to 997 only.

PST05R ROUTE FILE FULL

All records in the route-file are currently in use. Until one of the entries self-destructs (that is, when delivered to all cited users), n further POST commands can be accepted. Contact AFFIRMS staff.

READY This is a system level message as opposed to a program message. You h fallen out of the program. Enter "RUN" to access AFFIRMS or "BYE" to leave.

SSM02R C.O.F. NOT IMPLEMENTED, REGION: XX

The Current-Observation-File for the specified Region has not been constructed. Contact AFFIRMS staff.

SYN01A NOT ASSIGNED

SYN02A INVALID SYNTAX OR LINE GARBLE

This message can arise from any number of defects in command syntax o from telephone line noise which altered your input. See that the statement is entered correctly with a legitimate command VERB and tha command VERB is followed by a blank (if there are operands).

SYN03I NOT ASSIGNED

SYN03I NOT ASSIGNED

SYN04A TOO MANY OPERANDS

The command has more operands than are legal with the particular type of command.

SYN05A UNRECOGNIZED COMMAND (OR LINE GARBLE)

The command VERB is unrecognizable. The most likely cause is failure to place the single blank between the VERB and the first operand (for those commands with operands). A noisy telephone connection may also be responsible.

SYN06I END OF FILE ENCOUNTERED

AFFIRMS was in file-mode and finished processing the last command in the file. The terminal awaits a new command to be entered from the keyboard.

SYN07A CONSECUTIVE DELIMITERS

Two operand separators were found without any operand data between them. This could arise from comma-after-comma, comma-after-blank, or any other such combination. This message usually arises from placing more than one blank between two operands.

***UNASSIGNED, SEQ:XXX

This message probably indicates an AFFIRMS program bug. Report to AFFIRMS staff.

WHAT? A system level message indicating that you have fallen out of AFFIRMS. Enter RUN to access AFFIRMS or BYE to leave.

ZON01A WRONG NUMBER OF OPERANDS

Too many or too few operands were specified for a ZONE command.

ZON03A IMPROPER REGION NUMBER

REGION-NUMBER must be between one and 10.

ZON04A ILLEGAL FORECAST TIME

FORECAST-VALID-TIME must be two digits between 01 and 24.

ZON05A EXCESSIVE TREND

One or more data trends exceeded the limits imposed in the User's Guide. A zero-trend may be entered as "M" instead of "0" (zero).

ZON06A INVALID PRECIP. DURATION(S)

PRECIPITATION DURATIONS are limited to 16 and 8 hours, respectively, an their sum must not exceed 24.

ZON07A INVALID LIGHTNING-ACTIVITY LEVEL

LIGHTNING ACTIVITY is limited to the range one to six.

ZON08A STOW CONTAINS NO ZONE NUMBERS

A ZONE command specifying STOW rather than a single zone number has no been preceded by a STOW ZONE command.

ZON10I NO CURRENT OBS IN ZONE(S)

A ZONE command was entered but AFFIRMS could find no current (today's) for any of the stations in the zone. No forecasts were generated.

ZON11A IMPROPER ZONE NUMBER

Forecast zone numbers must be entered as a three-digit number between and 999.

ZON12R ELIGIBILITY TABLE OVERFLOW, LAST STATION TRENDED:xxxxxx

A ZONE command may not trend more than 40 stations, either in a singl zone or in a group of zones cited by STOW.

APPENDIX D

How AFFIRMS Determines the Displayed Adjective Class (AC)

In March 1974, Forest Service, BLM, and State Forestry representatives agreed on a standard for specifying the level of fire danger for public information. Most organizations are using the adjective class only for public information. Manning Class (appendix E) is used for in-house fire preparedness information. Note that MC-3 can have an AC of Moderate, High or Very High.

The adjective class is expressed as one of five levels; Low (L), Moderate (M), High (H), Very High (V), and Extreme (E). It is derived from a combination of Manning Class and Ignition Component as follows:

Ignition Component	0-20	21-45	46-65	66-80	81-100
Mannning Class (MC)		Adjective Class			
0 [1]	0	0	0	0	0
1-,1,1+	L	L	L	M	M
2-,2,2+	L	M	M	M	H
3-,3,3+	M	M	H	H	V
4-,4,4+	M	H	V	V	E
5	H	V	V	E	E

[1] The "zero" is included for those cases where AFFIRMS is not determining the station MC.

NOTE--THE ADJECTIVE CLASS IS FOR PUBLIC INFORMATION, IT HAS NO DIRECT CONNECTION TO FIRE BEHAVIOR!!!!

APPENDIX E

How AFFIRMS Determines The Displayed Manning Class (MC)

he National Fire Danger Rating System provides seven ratings for the use of the ire manager. Any one of the seven may be used as the basis for determining the anning class or readiness level of the suppression organization. The OPT command ermits you to specify which of those seven components or indexes are to be used as he Manning Index (MI). (See Section 2.1.3.)

or the Forest Service at the time of this writing, the 90th and 97th percentile urning Index values for each station's fuel models are used to determine manning lasses.** These percentile values are determined from a statistical analysis of istorical fire weather observations. These values provide the criteria for anking the relative severity of the burning conditions on a given day.

he MI90 and MI97 values are employed by AFFIRMS to generate a table of test values gainst which the Manning Index for each model can be compared. There are always 0 such test values, corresponding to a nine-class system (nine classes plus zero).

he actual number of manning classes in use by a given administrative unit, owever, may be any value from 3 to 9. For this reason, AFFIRMS always computes anning class based on a nine-class system, but what is displayed as manning class epends on a selection made when the OPT command for that station was entered. his operand, referred to in the User's Guide as "Number-of-Display-Classes" Section 2.1.3), is used to specify whether displays for that station will show ine classes, three classes, or some other number of classes.

**The Bureau of Land Management is using the 80th and 95th percentiles of the I.

The break-points used to determine the manning class in the nine-class system are as follows:

Computed Class Level	Upper Value For Class
0	MI=0
1	(MI90)/8
2	(MI90)/4
3	(MI90)(3/8)
4	(MI90)/2
5	(MI90)(3/4)
6	MI90
7	(MI90 + MI97)/2
8	MI97
9	More than MI97

The table that follows shows which of the nine-class manning class designators will appear for any number of selected manning classes. To use the table, use the row which shows the number of manning classes which your administrative unit employs. Across the row will be the displayed manning classes for each corresponding nine-

value.

Computed 9-Class Level	0	1	2	3	4	5	6	7	8	9
Desired # of Manning Classes	Displayed Manning Class									
3	0	1	1	1	1	1	1	4	4	5
4	0	1	1	1	1	3	3	4	4	5
5	0	1	1	2	2	3	3	4	4	5
6	0	1	1	2	2	3-	3+	4	4	5
7	0	1	1	2	2	3-	3+	4-	4+	5
8	0	1	1	2-	2+	3-	3+	4-	4+	5
9	0	1-	1+	2-	2+	3-	3+	4-	4+	5

APPENDIX F

How AFFIRMS Weights the Inputs to the DSPU Command

The DSPU command combines data from up to nine fire weather stations and produces an integrated fire danger rating. The manager must select the stations to represent the area and determine the influence that each station is to have on the weighted area fire danger--that is, the station weighting factor. The only requirement of AFFIRMS is that the weighting factors of the stations within the area add up to 100 percent.

The station weighting factor is based on the manager's local experience considering such things as: percent of the total area represented by this station; resource values; historic fire occurrence; and public use patterns. For a complete discussion of weighting factor selection see Deeming 1972.**

In the case of a missing station, its weighting factor will be distributed proportionally to the reporting stations. Consider a unit with three stations as follows:

Station	Weighting Factor (w)
A	22
B	44
C	34
	100

If Station C fails to report, the weighting factors will be reset as follows:

A $$100 \frac{22}{22 + 44} = 33$$

B $$100 \frac{44}{22 + 44} = \frac{67}{100}$$

** Deeming, John E. 1972. Fire Danger and Fire Weather Seminar, Interpretation and Application.

The Weighted IC

Using the above example, a weighted average IC for the Stations A, B, and C would be obtained as follows:

Station	Weighting Factor(w)	IC(i)	(w) (i)/100	AVG IC
A	22	38	8.36	
B	44	47	20.68	
C	34	58	19.72	
	100		48.76	round 49

The Weighted Manning Class

The manning classes must first be determined for each station using the nine-class system. (See appendix E.) Each is then assigned a factor according to the following schedule:

Manning Class	x	Class Factor (m)*
0	0	0
1-	1.25	1.19
1+	1.75	1.68
2-	2.25	2.37
2+	2.75	3.36
3-	3.25	4.76
3+	3.75	6.73
4-	4.25	9.51
4+	4.75	13.45
5	5.25	19.03

*$\text{Ln } m = x \text{ Ln}2 - \text{Ln}2$ where x = 1.25, 1.75, 2.25, 2.75, 3.25, 3.75, 4.25, 4.75, and 5.25

he weighted manning class would be determined as follows:

Station	Wt. Factor(w)	Man. Cl.	Class Factor (m)	(m)(w)/100
A	22	2-	2.37	.52
B	44	3+	6.73	2.96
C	34	4-	9.51	3.23
	100			= 6.71

he 6.71 is translated to a weighted manning class by use of the following table:

Weighted Manning Class	[(m)(w)/100]
0	0-0.99
1-	1.00-1.40
1+	1.41-1.99
2-	2.00-2.82
2+	2.83-3.99
3-	4.00-5.65
3+	5.66-7.99
4-	8.00-11.30
4+	11.31-15.99
5	16.00

n the example ([m] [w]/100) = 6.71. Therefore, the weighted manning class is 3+ r a High 3.

he Unit Adjective Rating (AC)

he unit adjective rating would be derived similarly to the station AC (appendix D) xcept that the unit weighted IC and MC would be used.

Wt. IC	Wt. MC	Unit AC
49	3+	H

APPENDIX G

Use Of AFFIRMS in Prescribed Burning Operations

AFFIRMS is designed primarily for the day-to-day processing of fire-weather observations. The system can also be used for prescribed fires by setting up "pseudostations."

By convention, the ARCHIVER program considers any station number whose last two digits are between 90 and 99 as a "pseudostation." Data entered for such a station are understood to be for field operational use, training, or for research. These observations are not archived. This permits you to assign a station number, enter observations for that station, and display indexes, but the data will not go into the permanent records.

Several weeks before your prescribed burn, you would enter the proper cataloging commands for your pseudostation (see Section 2.1),enter the first OBS, and set the 1000HR, X1000, and herb stage (see Sec. 4.3.3 COFMOD). When the catalog is completed, entry of the special observations can begin. Typically, personnel will visit the burn site and install a set of 10-hour fuel moisture sticks, a hygrothermograph, and a rain gauge. They will then return periodically to take weather measurements and weigh the sticks. In a few weeks the drying trend and daily fire danger fluctuations can be examined by running the observations through AFFIRMS standard procedures.

You should coordinate with your local fire weather forecaster during the period observations are being taken. He can obtain prescribed burn weather readings as well as routine weather observations.

If multiple weather readings are made each day in preparation for prescribed burn (for example, 0900, 1300, and 1800), special procedures are needed. The recommended method is to enter 1300 readings as regular OBS commands at the same time routine weather is entered. SPC commands should be used to enter additional readings and DSPX SPC commands used to display computed indexes. Three points should be remembered when using SPC commands:

a. It is cheaper to enter data only once daily;

b. Only one SPC observation is held for each station. If you want to send t or more SPC observations for each station to the fire weather forecaster you must construct a special file (see Section 1.7) which the weather forecaster can execute with a FILE READ command:

c. SPC commands cause no change in fuel moisture contents of heavier fuels (1000HR and 10000HR T/L fuels). The OBS command is necessary daily to correctly compute the heavy fuel moistures.

APPENDIX H

The Format of AFFIRMS Archived Fire Weather Data

Punch Card Format (Modified) for NWS-9a

Field Descriptions	Begin Col. #	End Col. #
Station Number	1	6
Date (yymmdd)	7	12
State of Weather		13
Dry-Bulb Temperature (Deg. F)	14	16
Relative Humidity, Percent	17	19
Not Used	20	22
Digit '9' If Fuels Wet		23
Herb-Veg-Code (Model 1) 1 = Pregreen 2 = Green 3 = Transition 4 = Cured 5 = Frozen		24
Man-Caused-Risk	25	27
Wind Direction (8 points)		28
Windspeed (miles per hour)	29	31
Not Used		32
10-Hr-T/L Moist. (Only if measured)	33	35
Not Used	36	38
Max. Temp. (Deg. F)	39	41
Min. Temp. (Deg. F)	42	44
Max. R.H. (Percent)	45	47
Min. R.H. (Percent)	48	50
Not Used		51
Precip. Duration (Hours)	52	53
Precip. Amount (Inches-100)	54	57

Field Descriptions	Begin Col. #	End Col. #
Lightning Act. Level	58	60
Digit "2"		61
Model 1 I.D.		62
Secondary Models:		
Model 2 I.D.		63
Not Used	64	65
Model 2 Herb-Veg-Code		66
Model 3 I.D.		67
Not Used	68	69
Model 3 Herb-Veg-Code		70
Model 4 I.D.		71
Not Used	72	73
Model 4 Herb-Veg-Code		74
Not Used	75	78
Forecast Flag 0 or blank = OBS 1 = FCST		79
Region Number		80

Explanatory Notes for Modified NWS-9a Card Format

The card images in the format described on the preceding page are generally generated by the archiving processor of the AFFIRMS program.

Some variations from the normal Weather Service WS D-9b form have been introduced. They are described below:

1) Because all humidity entries are converted by AFFIRMS to relative humidity (even though the input may have been wet-bulb, dewpoint, or R.H.) only the relative humidity is available for archiving. The presence of the digit "2" in card column 61 indicates that the data in columns 17-19 is relative humidity and not wet-bulb (which is standard for the WS-D9b).

2) The AFFIRMS system permits up to four fuel models to be associated with any given station. A separate herbaceous stage can be specified for each model. Because later use of this data may require these conditions (if live-fuels are involved, for example), the card format has been modified to include the first model's values in the normal position on the card (24) for herbaceous. The model identifier (a letter from A through U) for the first model is then placed in column 62. The other four models have their identification and herbaceous condition placed in columns 63 through 74.

3) In the Max/Min temperature and humidity fields, a value of 100 in both Max and Min indicates that both values were missing. Subsequent processing should make this check.

4) The Forest Service Region number (column 80) is included for convenience in sorting by the National Fire Danger Rating Library.

5) The wind direction eight-point code in the card images has been derived from the stored degrees-of-the-compass value. Some stations may enter wind direction in systems other than eight-point which offfer more resolutions, such as 16 point or degrees-of-the-compass. Such additional resolution is, of course, lost when this conversion to eight-point is made. Missing direction is recorded in the card images as "0".

) The 1-, 10-, and 100-hour timelag fuel moistures are only archived if ctually entered (nonmissing) in an observation. In all cases where these tems are computed from ambient conditions, they appear in the archived records s zero or blank.

7) For the period January 1973 through March 1975 AFFIRMS made only one consistency check on the precip. amount: values were required to be between 0 and 10.00 inches. Occasionally, field personnel would enter nine when they should have entered 0.90 or 0.09. These three values are all valid as far as the AFFIRMS program is concerned, so large precipitation amounts should be viewed with suspicion for this period.

APPENDIX I

How AFFIRMS Uses The Reported LALs

s explained in Deeming and others 1978 [1] lightning occurrence is meant to account or fires set by lightning on the day being rated and for fires set the previous ay not yet discovered that will have to be considered in the rated day's fire usiness (holdover fires). Three LOIs are calculated each day: yesterday's using he LOI from 2 days ago, yesterday's IC, and the LAL reported today that haracterizes the lightning situation that occurred yesterday (midnight to idnight); today's LOI using yesterday's "recomputed" LOI and today's predicted AL and observed IC; and tomorrow's LOI using today's preliminary LOI and omorrow's predicted LAL and IC.

everal LALs are either reported via the OBS command or are included by the fire eather forecaster in the FCST or ZONE commands. How these are used is explained n the following paragraphs:

btaining Yesterday's Lightning Risk

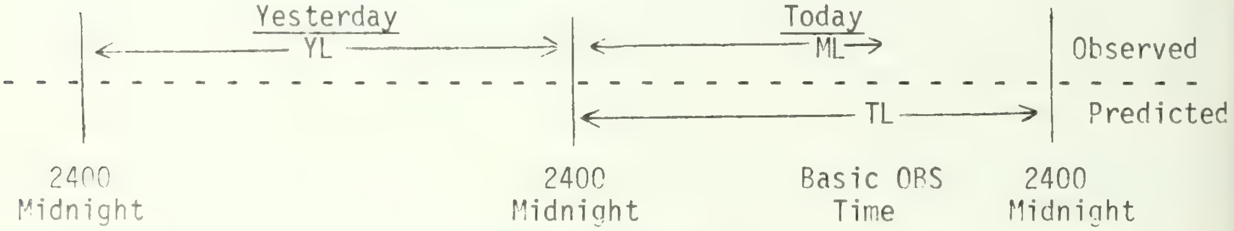
n LAL that best described the lightning occurrence from midnight to midnight the revious day is reported in the OBS command. It is abbreviated "YL" for esterday's Lightning. YL actually replaces the LAL used to calculate yesterday's reliminary LOI in yesterday's fire weather record. It is YL that eventually is ade part of the archived weather of the National Fire Weather Library and used by IRDAT. So it is very important that careful consideration be given to the ssignment of that value.

---

[1] Deeming, John E., Robert E. Burgan, and Jack D. Cohen. 1978. The National ire-Danger Rating System - 1978. USDA Forest Service General Technical Report NT-39. Intermountain Forest & Range Experiment Station, Ogden.

Obtaining Today's Lightning Risk for the Current Day's Observed Fire Danger Rating

The LAL used to determine the current day's LR in the processing of this afternoon's fire weather observation is an estimate of what today's LAL will be. As of basic observation time, two LALs are available for the computer to choose from; the LAL predicted on yesterday's fire weather forecast for today, TL (for Tomorrow's Lightning), and the LAL reported as item 6 of the OBS command that describes the lightning occurrence experienced between midnight last night and basic observation time. ML (for this Morning's Lightning). AFFIRMS chooses the higher of these two LALs. Remember that this value will be replaced in the fire weather record by the YL reported tomorrow.



Where:

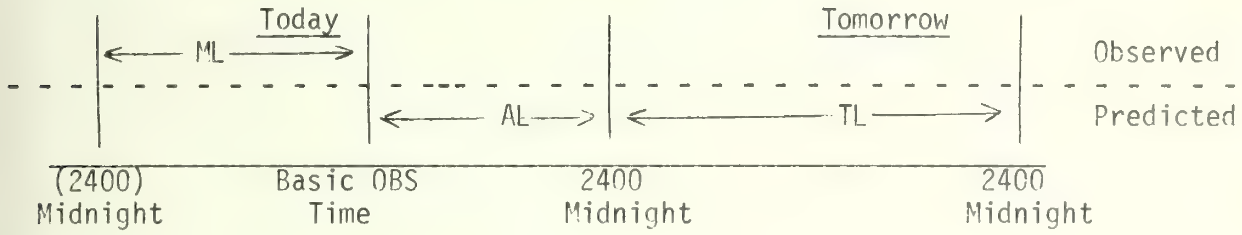
"YL" is the observed LAL for yesterday;
"ML" is the observed LAL today since midnight;
"TL" is the LAL predicted yesterday for all of today.

Obtaining Today's Lightning Risk for Predicting Tomorrow's Fire Danger Rating

Keep in mind that this determination takes place after the current day's fire weather observation is available. AFFIRMS makes a second estimate of an LAL fo the current day choosing the highest of the ML (reported in the fire weather observation) and the LAL predicted for the period from basic observation time t midnight of the current day. This LAL is the AL, an abbreviation for Afternoon Lightning. AFFIRMS uses this LAL, the IC from the observation and the LOI from yesterday to recalculate a LOI for today. This updated LOI will be used in the prediction of tomorrow's LOI.

Obtaining Tomorrow's Lightning Risk for Predicting Tomorrow's Fire Danger Rating

This one is simple and straight forward: the TL included on the FCST or ZONE for tomorrow is used.



Where:

"ML" is the LAL observed today since midnight.
"AL" is the LAL predicted for the remainder of today (basic observation time to midnight) on today's forecast.
"TL" is the LAL predicted for tomorrow.

NOTE: Lightning Risk is calculated from the appropriate LAL and the Lightning Risk Scaling Factor.

Coding Forms and Worksheets

Exhibit I	'OBS' Coding Sheet
II	'SPC' and 'ARCH' Coding Sheet
III	'FCST' Coding Sheet
IV	'ZONE' Coding Sheet
V	Station Catalog Worksheet

'OBS'

AFFIRMS CODING SHEET

COM- MAND	STATION NUMBER **(6)	OBS TIME (2)	1. W (1)	DRY TEMP. (1)	HUM* ENTRY (1)	2. ML (1)	MR (1)	WIND		10hr T/L (1)	TEMP.		% RH		PRECIP.		3. YL (1)	4. MR (1)	5 UNKO (0)
								DIR. (1)	SPD. (1)		MAX. (1)	MIN. (1)	MAX. (1)	MIN. (1)	DUR. (1)	AMOUNT (1)			
OBS	------	--	-	----	---	-	---	---	--	----	---	----	---	---	---	-----	-	----	------
OBS	------	--	-	----	---	-	---	---	--	----	---	----	---	---	---	-----	-	----	------
OBS	------	--	-	----	---	-	---	---	--	----	---	----	---	---	---	-----	-	----	------
OBS	------	--	-	----	---	-	---	---	--	----	---	----	---	---	---	-----	-	----	------
OBS	------	--	-	----	---	-	---	---	--	----	---	----	---	---	---	-----	-	----	------
OBS	------	--	-	----	---	-	---	---	--	----	---	----	---	---	---	-----	-	----	------
OBS	------	--	-	----	---	-	---	---	--	----	---	----	---	---	---	-----	-	----	------
OBS	------	--	-	----	---	-	---	---	--	----	---	----	---	---	---	-----	-	----	------
OBS	------	--	-	----	---	-	---	---	--	----	---	----	---	---	---	-----	-	----	------
OBS	------	--	-	----	---	-	---	---	--	----	---	----	---	---	---	-----	-	----	------
OBS	------	--	-	----	---	-	---	---	--	----	---	----	---	---	---	-----	-	----	------

1. State of Weather

2. LAL for period since midnight to basic obs. time (ML).

3. Yesterday's 24-hour (0001-2400) lightning activity (YL).

4. Tomorrow's Forecasted Man-Caused Risk

*Relative Humidity,, Dew-point Temp. or Wet-bulb Temp.

**Minimum Number of Digits. "Dashes" indicate maximum length.

5. Miscellaneous information listed only on DSPW command. Data not archived.

'SPC' and 'ARCH'

AFFIRMS CODING SHEET

								WIND			TEMP.		% RH		PRECIP.			
COMMAND **(3)	STATION NUMBER (6)	OBS TIME (2)	1. W (1)	DRY TEMP. (1)	HUM.* ENTRY (1)	2. ML (1)	MR (1)	DIR. (1)	SPD. (1)	10hr T/L (1)	MAX. (1)	MIN. (1)	MAX. (1)	MIN. (1)	DUR. (1)	AMOUNT (1)	3. YL (1)	*** DATE
----	------	--	-	----	-----	-	---	---	--	----	---	-----	---	---	---	-----	-	______
----	------	--	-	----	-----	-	---	---	--	----	---	-----	---	---	---	-----	-	______
----	------	--	-	----	-----	-	---	---	--	----	---	-----	---	---	---	-----	-	______
----	------	--	-	----	-----	-	---	---	--	----	---	-----	---	---	---	-----	-	______
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----	------	--	-	----	-----	-	---	---	--	----	---	-----	---	---	---	-----	-	______

1. State of weather

2. LAL for period since midnight to basic obs. time (ML)

3. Yesterday's 24-hour (0001-2400) lightning activity level (YL).

*Relative Humidity, Dew-point Temp. or Wet-bulb Temp.

**Minimum Number of Digits "Dashes" indicate maximum length.

***Note entered-- for documentation only

'FCST'

AFFIRMS CODING SHEET

COM-MAND	STATION NUMBER	VALID TIME	1. W	DRY TEMP.	RH	LTG ACT		WIND		10hr T/L	TEMP.		% RH		PRECIP DUR.		***
	**(6)	(2)	(1)	(1)	(1)	AL (1)	TL (1)	DIR. (1)	SPD. (1)	(1)	MAX. (1)	MIN. (1)	MAX. (1)	MIN. (1)	D1 (1)	D2 (1)	DATE
FCST	------	--	-	----	---	-	-	---	--	----	---	----	---	---	--	---	
FCST	------	--	-	----	---	-	-	---	--	----	---	----	---	---	--	---	
FCST	------	--	-	----	---	-	-	---	--	----	---	----	---	---	--	---	
FCST	------	--	-	----	---	-	-	---	--	----	---	----	---	---	--	---	
FCST	------	--	-	----	---	-	-	---	--	----	---	----	---	---	--	---	
FCST	------	--	-	----	---	-	-	---	--	----	---	----	---	---	--	---	
FCST	------	--	-	----	---	-	-	---	--	----	---	----	---	---	--	---	
FCST	------	--	-	----	---	-	-	---	--	----	---	----	---	---	--	---	
FCST	------	--	-	----	---	-	-	---	--	----	---	----	---	---	--	---	
FCST	------	--	-	----	---	-	-	---	--	----	---	----	---	---	--	---	

1. State of Weather

**Minimum Number of Digits-"Dashes" indicate maximum length.

***Not entered-for documentation only.

'ZONE'

AFFIRMS CODING SHEET

COM-MAND	ZONE NUM. **(3)	REG. NUM. (1)	VALID TIME (2)	1. W (1)	TEMP. TREND (1)	RH TREND (1)	WD SPD TREND (1)	PRECIP DUR		TEMP TRENDS		RH TRENDS		LTG ACT		10hr T/L TREND (1)	***
								D1 (1)	D2 (1)	MAX. (1)	MIN. (1)	MAX. (1)	MIN. (1)	AL (1)	TL (1)		DATE
ZONE	---	--	--	-	---	---	---	--	--	---	---	---	---	-	-	-----	------
ZONE	---	--	--	-	---	---	---	--	--	---	---	---	---	-	-	-----	------
ZONE	---	--	--	-	---	---	---	--	--	---	---	---	---	-	-	-----	------
ZONE	---	--	--	-	---	---	---	--	--	---	---	---	---	-	-	-----	------
ZONE	---	--	--	-	---	---	---	--	--	---	---	---	---	-	-	-----	------
ZONE	---	--	--	-	---	---	---	--	--	---	---	---	---	-	-	-----	------
ZONE	---	--	--	-	---	---	---	--	--	---	---	---	---	-	-	-----	------
ZONE	---	--	--	-	---	---	---	--	--	---	---	---	---	-	-	-----	------
ZONE	---	--	--	-	---	---	---	--	--	---	---	---	---	-	-	-----	------
ZONE	---	--	--	-	---	---	---	--	--	---	---	---	---	-	-	-----	------

1. Forecasted State of Weather

**Minimum Number of Digits

***Not entered--
for documentation only.

STATION NAME ____________ STATION NUMBER _ _ _ _ _ _ DATE ________ PREPARED PY ________

AFFIRMS COMMAND	OPERANDS	USER'S GUIDE PAGE REFERECE
CTLG	Station Number, Elevation, Local Standard TimeZone, Unit Abr., Region #, Agency, Local Std. OBS Time, Fire Weather Zone, Station Abrev. ------,-----(1,5),---. ----, --(1,2), -, --, ---, ------(1,6)	2.1.1
HDEF	Station Number, Humidity code: English 1 = wet bulb temp, 2 = RH, 3 = dewpoint temp; Metric (temperatures and wind speed) 4 = wet bulb temp, 5 = RH, 6 = dewpoint temp ------,-	2.1.2
OPT	Station Number, Number of Display Classes, Manning Index, Associated Station, Lightning Scaling Factor, Date of Fuel Stick Exposure (yymmdd) ------, -, --, ------, ----, ------	2.1.3
LOC	Station Number Latitude Longitude Aspect Site ------, -----, -----, -, -	2.1.4
MODL	Station Number, Climate Class Fuel model Slope Grass type, 90-97%, (as many as three additional sets of model-slope-grass, and percentiles may be entered) ------, -, ---,------(4,6),---,------(4,6)---,-------(4,6)---,------(4,6)	2.1.5
HERB	Station Number, Model, Stage = Green Cured Frozen (as many as three additional sets of model and herbaceous stages can be entered) ------, -, -, -,-, -,-, -,-	2.1.6
WOOD	Station Number, Measured Woody Moisture Content ------, --- (2,3)	2.1.7
DESC	------ (enter a station number to receive a sstation description)	2.1.8

Helfman, R. S., R. J. Straub, and J. E. Deeming.
1980. User's Guide to AFFIRMS: Time-share computerized processing for fire danger rating. USDA For. Serv. Gen. Tech. Rep. INT-82, n.p. (150 p.). Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

This User's Guide is a comprehensive manual for persons accessing the 1978 version of the National Fire Danger Rating System through AFFIRMS. This document supercedes the August 1975 User's Guide to AFFIRMS published as General Technical Report RM-15. AFFIRMS is a user-oriented, interactive computer program which processes weather observations and fuels data to produce indexes of probable forest fire danger. The Guide is written in nontechnical language for persons without a computer background.

KEYWORDS: fire danger rating; computerized systems

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KEYWORDS: fire danger rating; computerized systems

The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

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Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

: INT - 83

EVEN-AGED MANAGEMENT:

Basic Managerial Questions and Available or Potential Techniques for Answering Them

David W. Hann
J. Douglas Brodie

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General Technical Report INT-83
INTERMOUNTAIN FOREST AND
RANGE EXPERIMENT STATION
U.S. Department of Agriculture • Forest Service
Ogden, Utah 84401

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RESEARCH SUMMARY

Major stand-level and forest-wide decisions facing forest managers interested in applying even-aged management are identified. Traditional, current, or potentially useful techniques for making these decisions are reviewed. Emphasis is placed upon how each method characterizes the stand or forest, the growth and yield information requirements of each method, the computational burden associated with each method, and the flexibility of each method and its adaptability to the form and complexity of the solution.

USDA Forest Service
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September 1980

EVEN-AGED MANAGEMENT:

Basic Managerial Questions and Available or Potential Techniques for Answering Them

David W. Hann
J. Douglas Brodie

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
U.S. Department of Agriculture
Forest Service
Ogden, Utah 84401

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INTRODUCTION

Effective planning and conduct of a forest management program requires the forest manager to make a number of basic decisions; therefore a thorough understanding of the major questions prefacing these decisions is critical in forest management planning. Once the specific questions or decisions have been defined and understood, the forest manager chooses the particular analytical tool or tools to help in decisionmaking. Because a great deal of management science research has been devoted to developing alternative analytical tools, deciding which is best for a particular need can be difficult. The purpose of this study, therefore, is to examine the basic questions facing the manager interested in practicing even-aged forest management and to explain and evaluate the various analytical tools historically, currently, or potentially useful in answering the questions. Evaluation criteria will include: the way a particular method characterizes the stand or forest; the growth and yield information requirements of the method; the computational burden associated with the method; the flexibility of the method as to the form and complexity of the solution; and other pertinent considerations. A similar study has recently been reported for uneven-aged management (Hann and Bare 1979).

Management Questions

The basic timber management question is simply: What treatment should be applied to each stand each year to best meet the objectives established for the forest? The term "treatment" includes inaction.

This apparently simple question is actually very complex and difficult to answer. The manager is faced with a forest composed of perhaps hundreds of stands; a myriad of potential treatment types, intensities, and timings from which to choose for each stand; and also with an increasingly complex set of objectives and constraints for the forest. Even in the early days of forest management when forestry objectives were simpler and the set of possible treatments was relatively simple (that is, harvest cut or not), finding an answer to the basic question was difficult.

The basic question historically has been divided into a number of subordinate questions perhaps with the belief that answering subordinate questions would be easier. These subordinate questions can be separated into two categories: stand- (or aggregrated stand-) level questions and forest-level questions.

For stands (or stand classes), the manager interested in practicing even-aged management needs to know the optimal:

1. Species mix
2. Planting density
3. Thinning plan
4. Fertilization plan and
5. Rotation length.

While it has not been done historically, 2, 3, and 5 from above could be combined into the question, "What is the optimal diameter or size distribution schedule?"

The term "stand classes" refers to the practice of aggregating stands of similar species mix, site quality, and age into classes to reduce the compexity of the problem. An "optimal" solution to a specified problem is defined to be that solution which best, or most favorably, meets the specified objectives and constraints of management. As defined, a plan includes both the schedule and intensity of treatment.

At the forest level, the forest manager interested in applying even-aged managemen is faced with determining, for the desired number of planning periods, the optimal:

1. Schedule of stand (or stand class) treatments and/or
2. Conversion strategy and conversion period length.

The two questions are closely related because a conversion strategy is also a schedule of stand treatments. The second question differs from the first if a targeted forest structure exists. Then the problem becomes how to best convert the present forest structure to the targeted structure while meeting the objectives and constraints of management. A regulated forest is an example of a targeted forest structure. Selecti among alternatives for meeting one or several targeted forest structures constitutes the conversion strategy decision. The body of methods used are known as harvest scheduling techniques. Solution of these problems provides the allowable cut for each planning period.

The above questions can be regarded as basic questions as well as the set of problems dealt with in this paper. The techniques discussed in this paper can also be applied to make such subsidiary decisions as:

1. Selection of the most efficient logging techniques to achieve specific stand objectives (Sessions 1979)
2. Selection of the optimal harvesting schedule and of stand protection treatmen in the face of such damaging agents as forest pests (Brodie and Rose 1975)
3. Selection of the optimal schedule over time for both stand treatment and roading access (Navon 1976).

These applications depend upon a thorough understanding of the basic stand treatment a harvest scheduling questions. They will be elaborated on further in this paper.

TRADITIONAL SOLUTION METHODS

The two questions which have been studied the longest have been rotation length a the scheduling of stand class treatments to determine the allowable cut.

Traditional Rotation Length Methods

As stated by Davis (1966), numerous criteria have been proposed to determine rotation length including: product size, culmination of mean annual increment, maximu forest rent, and maximum soil expectation value. The product size criterion assumes that the objective of management is to grow a certain size of tree (for example, pulp size trees or saw-log size trees). Rotation length is equivalent to the time it take a stand of specified species mix and site quality to reach the desired size.

Culmination of mean annual increment (MAI) defines the age from time of regeneration, at which average annual growth, in volume, is maximum. Rotation lengths set to this age will maximize the physical productivity of the stand. The age at which culmination occurs will vary depending upon the species mix and site quality of the stand and upon the measure of volume. Culmination of MAI will occur sooner when expressed in total stem cubic foot volume than it will if expressed in board foot volum (Davis 1966).

Maximum forest rent is conceptually identical to culmination of MAI, the only difference being that the latter maximizes average annual volume growth while the former maximizes average annual net value growth. For a given stand age, annual net value growth is the gross value of the timber minus growing costs all divided by the stand age (Davis 1966). As an economic criterion for determining rotation length, this method has been strongly criticized for ignoring the opportunity cost incurred by locking up capital in a forest investment.

The final method, maximum soil (or land) expectation value, does include the opportunity cost of capital. The first step in computing rotation length using maximum soil expectation value is to determine, for a given rotation length and interest rate, the present net worth of all costs and returns, incurred and/or received during the rotation. Soil expectation value of the specific rotation length is then computed as the present value from receiving an infinite series of these present net worth "payments." This process is repeated for a number of rotation lengths and the rotation with the largest soil expectation value is chosen. The rotation of maximum soil expectation value will provide the owner with the highest return on investment in the property at the specified discount rate (Davis 1966).

Evaluation of Traditional Rotation Length Methods

HARACTERIZATION OF THE STAND

Traditional methods require the stand to be characterized by those factors needed o obtain access to the particular yield tables used in the method's analysis. These actors usually include site quality, stand age, and species.

ROWTH AND YIELD INFORMATION

Because all traditional methods use yield information, the assumptions incorporated n the yield information will subsequently be used in determining the rotation length. or example, if normal yield tables for unmanaged stands are used, it is assumed that e stand will be fully stocked throughout its life span and that no mortality capture thinning will occur. On the other hand, if the yield tables incorporate specified inning plans then it is assumed that the thinnings will occur on the specified hedules and with the specified intensity. While all methods do determine an optimal tation length based on their specific criteria, it should not be assumed that the lution also represents the optimal treatment program for the stand. Rather, the lution is optimal for the given treatment program incorporated in the yield tables.

MPUTATIONAL BURDEN

All traditional methods can be done by hand. The product size criterion is the smplest method to apply, while the maximum soil expectation method requires the most iformation and is the most difficult to compute.

FEXIBILITY OF SOLUTION SPECIFICATIONS

Each traditional method has been designed to meet a specific objective. The oective of the product size criterion is to produce trees of a specified, fixed size. Th objective of the maximum mean annual increment criterion is to produce the greatest amunt of wood volume possible, while maximum forest rent has the objective of producing th greatest average annual net value of the stand for a single rotation. Finally, the oective of the maximum soil expectation criterion is to produce the greatest discounted ne value of the stand for an infinite number of rotations.

Traditional Methods for Scheduling Stand Treatments to Determine Allowable Cut

The other question that has historically received much attention is the schedulin of stand class treatments to determine allowable cut. Three methods have been used to find solutions to this problem--volume control, area control, and area-volume check.

Of the three methods, volume control requires the least amount of information to apply. No stand or stand class information is required and so allocation of the computed cut to actual stands must be accomplished after the fact. The goal of volum control is to provide a constant volume of cut over a specified period. Many formula have been developed to compute the allowable cut in this fashion. Some of the best kr include: the amortization formula, Von Mantel's formula, Grosenbaugh's formula, Hundeshagen's formula, the Austrian formula, Hanzlik's formula, Black Hills formula, and Kemp's formula (Davis 1966).

The objective of the area control method is to convert the forest to a regulated state witin one rotation period by cutting equal areas in each planning period. For forests of homogenous type and productivity, the determination and allocation of the allowable cut is simple. After deciding upon a rotation length for the type, the number of acres cut each year is simply the total forest area divided by rotation len in years. The usual rule for allocating the area cut to the forest is: oldest stands are cut first. Therefore, by knowing the age and corresponding volume of each stand (or stand class), both the schedule of stand class treatments (assumed to be final harvest) and the volume removed in each planning period can be determined (Davis 1966

If the forest is composed of a number of forest types and land productivity clas (which is most often the case), application of area control becomes more difficult. traditional approach to this problem has been to express the different productivity a type classes in equivalent productivity units. The units are usually expressed as th fractional number of acres needed to produce a constant volume in regulated final harvest. Therefore, the method becomes productivity unit control instead of true are control (Davis 1966). Electronic computers have simplified the application of areas (or productivity unit) control to these more complex problems. Program AREA (Sassama and Chappelle 1967) is an example of an area control computer program.

If a regulated forest structure exists, then both of the preceding control metho can provide a constant allowable cut, with equal areas (or productivity units) being harvested in each planning period. Regulated forests are, however, not usually encountered, which leads to problems. When applied to an unregulated forest, volume control results in an erratic number of acres being harvested while area control produces an erratic volume cut. The annual harvest calculated by one of the volume control formulas will be only a crude approximation of the true optimal harvest that can be sustained during conversion to a targeted forest. Because of these problems, third methodology of scheduling stand class treatments to determine allowable cut ha evolved, the area-volume check method.

The area-volume check method really covers a great number of techniques, all of which try to combine features from both the volume and the area control methods. Because of this diversity, it is difficult to generalize about the procedures. All methods do, however, require detailed information about the forest and its stands or stand classes, and assume that the conversion period equals the rotation length. Mo methods also require a great deal of tedious calculation to determine an allowable c figure. The last feature has made the introduction of the electronic computer to so area-volume check problems a blessing to many foresters.

As an example of area-volume check, the following is a brief description of a method once widely used by Region 6 (Pacific Northwest) of the USDA Forest Service (Chappelle 1966). The first step in this method is to obtain an initial estimate of allowable cut through the use of volume control formulas such as Hanzlik's formula. The stand (class) data are arranged by cutting priority, which is usually "oldest stands first." The time required to harvest each stand class is then calculated using the initial allowable cut estimate. Given the initial age of the stand class and the time required to cut it, the expected yield from each stand class at final harvest is calculated by projection. After harvest of all initial stand classes in the forest, two checks are made. The first examines whether the actual time needed to completely harvest the forest equals the desired conversion period and the second examines whether the acreage harvested each year is acceptable. If either of these checks are unacceptable, then the allowable cut is changed in a systematic fashion and the process is repeated. Chappelle (1966) incorporated these steps in the computer program ARVOL to actually perform the operations.

Evaluation of Traditional Stand Treatment Scheduling Methods

CHARACTERIZATION OF THE FOREST

Volume control through formula does not need to characterize the forest because it does not provide a schedule of stand treatments. The other two traditional methods characterize the forest by lumping stands into rather broad classes that are usually defined by age and perhaps site quality.

GROWTH AND YIELD INFORMATION

Treatment plans and their yields are fixed for each application of the method. Except for repeated solutions, no choice of how a stand class can be treated is provided; or example, runs with and without thinning might be compared. In addition, thinning uts can only be expressed as increases in final harvests or as priority harvests (that s, thinning harvests must be taken before regeneration harvests).

OMPUTATIONAL BURDEN

All of the traditional methods can be computed by hand. Volume control through ormula is the easiest to compute, while the area-volume check method is the most ifficult and tedious technique to apply.

LEXIBILITY OF THE SOLUTION SPECIFICATION

None of the traditional methods can handle economic criteria for stand treatment cheduling.

HER CONSIDERATIONS

Both area control and area-volume check assume that the conversion period equals te rotation length and that a targeted forest structure exists. In addition, the hrvest priority of their stand classes must be set before applying the two methods. Sch rules as cut oldest stands first or cut highest volume stands first determine the hrvest priority.

OPERATIONS RESEARCH METHODS

The introduction of both the electronic computer and operations research techniqu greatly expanded the manager's ability to answer questions pertaining to even-aged sta and forests. Some of the first applications of the computer were to mechanize the computations of numerical values previously, and tediously, done by hand, such as the aforementioned allowable cut methodologies. Two broad areas of operations research ha seen application to forestry problems, simulation and optimization.

The distinction between simulation techniques and optimization techniques in even-aged stand and forest-level analysis is not distinct because of confusion in usage. Confusion arises from a body of intermediate methods lumped together under the term "binary search techniques." We will distinguish between pure simulation, pure optimization, and binary search techniques. For the purpose of categorization, we will, however, follow the usage of Johnson and Tedder[1] and lump the binary search techniques under simulation.

A pure simulation approach requires that the analyst specify the entire treatment plan for each stand. The simulation tool used provides a detailed report of the impac of these decisions. Sensitivity to changes in these decisions is provided by repeate simulation analysis under alternate treatment plans. The alternative selected would b the best of all alternatives tried, judged against some implied objectives and set of constraints. Superior alternatives could easily exist, but may be missed.

Under a pure optimization approach, the analyst supplies only a specific objecti and a set of alternatives and constraints. The optimization technique then proceeds to find the best level of the objective criterion that can be met under the specification. No superior solution to this particular specification will exist. Of course, the analyst can check the sensitivity of his plan to alternate specifications of the problem through additional output provided or by resolving the problem under alternat specifications. Pure optimization applications to even-aged management have used mathematical programing techniques including: dynamic, linear, nonlinear, goal, and integer programing. These applications will be discussed.

Binary search techniques codify the repeated trials implicit in the pure simulat approach. Advantage can be taken of knowledge about the structure of forest manageme problems to efficiently solve some but not all potential problem specifications. The binary search techniques will give answers identical to the pure optimization techniq under certain objective criteria and constraint ranges, but different and lower value solutions under others. Currently, binary search techniques provide greater flexibil in handling complex sets of regional inventory data involving multiple ownerships and forest types with different allowable cut assumptions.

SIMULATION

Simulation Methods for Answering Stand-Level Questions

A good deal of work has been done in applying pure simulation to answering stand level questions. As examples, the work of Hamilton and Christie (1974) in Great Brit of Myers (1969, 1973) in the Rocky Mountain area, and of Hoyer (1975) in Washington a of interest. All three methods use a stand development model in a manner which allo the user to modify the thinning plan and the rotation length in order to analyze the possible consequences of the specified management program. Each simulation run produ information concerning stand development, yields from thinning and harvest cuts, and present net worth based on discounted costs and revenue figures. This information is reviewed by the user (the forest manager) to see if the particular solution looks "best" when compared to other selected management programs.

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[1] Johnson, K. Norman, and Philip L. Tedder. Linear programming vs. binary search in allowable cut calculation. For. Sci. [in preparation].

In addition to examining thinning plans and rotation lengths, Hamilton and Christie (1974) provide the user with an opportunity to examine initial planting densities, while Hoyer (1975) provides the means of examining the effects of fertilization at one intensity.

Evaluation of Simulation Methods for Answering Stand-Level Questions

CHARACTERIZATION OF THE STAND

The particular data items used to characterize the stand depend upon the type of stand development model used by the simulation method. These data items can range from site index, stand age, and stand basal area and/or total number of trees to site index, stand age, and the size and competitive position of individual trees within the stand.

GROWTH AND YIELD INFORMATION

Stand simulation methods can be applied to any kind of existing stand development model. With the use of more current stand development models, it is often possible to predict yields from a wide array of treatment plans.

COMPUTATIONAL BURDEN

Most stand simulators require a computer to operate.

FLEXIBILITY OF THE SOLUTION SPECIFICATION

While the stand simulation methods can be used to assess either physical or economic objectives, the methods cannot assure that the examined management program represents he "global" optimal solution to any specified set of complex objectives, constraints, nd cost-revenue relationships. To determine a global or near global optimal solution ould require a great number of simulations and careful analysis and can be accomplished ore efficiently by optimization for many stand development models.

Simulation Methods for Answering Forest-wide Questions

Simulation has also been used extensively in answering forest-level questions, ven before the introduction of the electronic computer. The area-volume check method s an example of a precomputer binary search simulation method. The computer has, of ourse, increased the manager's capability to utilize simulation. It has increased he size and complexity of problems that can be addressed with simulation and has hortened the time and tedium associated with obtaining a solution. Some recent amples of where binary search simulation has been employed for answering even-aged nagerial questions are the programs: SORAC (Chappelle and Sassaman 1968), SIMAC assaman and others 1972), and TREES (Tedder and others 1980). An example of an plication of pure simulation is program TEVAP2 (Myers 1970; Edwards and others 1973; ers 1974).

Program SORAC can compute an allowable cut using either area control or area-volume check. The program allows the manager to apply either method to each planning period in the planning horizon. If area control is chosen for every period with constant parameters, then the solution is identical to that computed by program AREA. Area control parameters that change between periods will, however, provide results that differ from AREA. When the area-volume check method is specified for the entire planning horizon, the results from SORAC also differ from those computed by ARVOL.

Program ARVOL computes an allowable cut that can be sustained for the conversion or rotation period. Using this method, however, can cause the allowable cut to change drastically after the conversion period or first rotation. Also, a manager rarely computes an allowable cut that will be followed for an entire conversion or rotation period. Instead, he will apply the cut during the current planning period and recomput a new allowable cut figure at the start of the next planning period. Using this contin updating feature, drastic changes in allowable cut from one planning period to the next can be avoided. SORAC basically tries to simulate this actual planning and updating process. While the allowable cut for the current planning period is the same as that provided by ARVOL, the advantage of SORAC over ARVOL is that SORAC provides the manage with a more realistic picture of the long-term consequences of his actions.

Like ARVOL and AREA, SORAC characterizes the forest by stand classes that are usually based on stand age. Finally, either extensively or intensively managed yields can be specified for each stand class, with intensive yields implying a predetermined treatment schedule.

In program SIMAC, the forest is also characterized by stand age classes, with a user-specified average site index for the whole forest. SIMAC, however, allows much more flexibility in specifiying a treatment scheme for testing than SORAC. SIMAC also differs through its allowable cut procedures. First, no rotation or conversion period length is specified. Instead, the length of the planning horizon is specified (up to 40 decades) along with the youngest age in which a stand class can be regeneration harvested. To meet the allowable cut, the simulation can harvest a stand class at any age down to the minimum age (that is, final harvest age is not predetermined).

The second difference is that an age-related cutting priority can be specified instead of assumed. A third difference is that a fixed allowable cut can be specified for any or all of the first 10 decades. Finally, an upper and lower bound on allowabl cut can be specified and the SIMAC program will compute, if possible, the maximum allowable cut per decade that can be removed over the planning horizon and still be within these bounds. The allowable cut technique used by SIMAC is a systematic trial and error process like that used by ARVOL. In fact, the allowable cuts would be ident cal in both if the bounds did not interfere with the process (and if the user did not require specific allowable cuts in the first 10 decades).

The TREES model (Tedder and others 1980) is a package of binary search techniques embodying the alternatives of area control, volume control, SIMAC, SORAC, or ECHO type approaches (ECHO is discussed under optimal forest-wide decisionmaking methods). A high degree of flexibility in specification can be maintained for:

1. Harvest priority;

2. Variable silvicultural intensity over time and portions of the inventory;

3. Alternate independent or interdependent methods and criteria for determining the harvest for subsets of the inventory such as public or private;

4. Resolution of results by timbershed, ownership, species, site, and prescribed silvicultural treatment.

The higher degree flexibility than that available from the pure optimization packages presently available has resulted in these techniques being chosen for detailed regiona projections (Beuter and others 1976).

The final example of an allowable cut simulator is program TEVAP2. Besides being a pure rather than binary search method, this program has a number of features which distinguish it from SORAC, SIMAC, and TREES. First, TEVAP2 deals with stands rather than stand classes. The stands must be even-aged with one or two stories, but they can be uniquely characterized by their type; site index; and the average diameter, height, number of trees, age, and dwarf mistletoe rating of the overstory and understory. For this reason, average or "normal" stands are not assumed and treatments can be better tailored to the actual stand. It should be noted that Myer's (1968, 1973) stand simulators can easily be used to derive the treatment schedule to be used in this forest-level analysis.

The second distinguishing feature of TEVAP2 is its planning horizon. In TEVAP2, the planning horizon is equal to the planning period and, for many users, the planning period is one decade. TEVAP2, therefore, is a short-range planning tool when compared to SORAC, SIMAC, and TREES.

Allowable cut determination methodology is the final distinguishing feature of TEVAP2. Four allowable cut levels are computed for the planning period. The first allowable cut figure is calculated under the assumption that all specified treatments are applied to optimally stocked stands existing in a forest with a perfectly balanced age structure. The second allowable cut is calculated under the assumption that all specified treatments are applied to the existing stands and forest structure. The third cut is computed by applying area regulation to the existing forest structure. The final allowable cut value is computed by volume control using a modified version of the Austrian formula.

The allowable cut figures are not applied to the existing forest structure for the conversion or rotation length to determine if they can be sustained. Rather, these cuts serve as guides and the forest manager can redefine treatment schedules and intensities if he is not pleased with the results.

Evaluation of Simulation Methods for Answering Forest-wide Questions

HARACTERIZATION OF THE FOREST

Some forest-wide simulation methods (for example, SORAC and SIMAC) characterize he forest by combining stands into classes using stand age, site quality, and/or pecies. Other forest-wide simulation methods (for example, TEVAP2 and TREES) charac erize and maintain each stand of the forest using detailed stand information.

ROWTH AND YIELD INFORMATION

Some forest-wide simulation models, such as SORAC, SIMAC, and TREES, use tabular ield information which can be derived from any yield source. Other forest-wide imulation models, such as TEVAP2, have stand development models built into them. These tand development models usually have been of the whole stand type. Unlike the raditional forest-wide decision methods, all of the aforementioned forest-wide imulation methods, except SORAC, allow thinning yields to be credited to total harvest hen they occur instead of at the final regeneration harvest cut.

OMPUTATIONAL BURDEN

All of the forest-wide simulation methods used as examples require a computer to erate. When compared to forest-wide optimization techniques, simulation methods are ten faster to run on the computer and therefore cheaper (Johnson and Tedder[1]).

FLEXIBILITY OF THE SOLUTION SPECIFICATION

Simulation methods SORAC, SIMAC, and TEVAP2 are used exclusively for seeking the objective of physical wood production. Program TREES can be used to meet either physical or economic objectives. As with the stand-level simulators, the treatment schedules and intensities are fixed for the run while cutting priority may be fixed by the simulation method. To determine a truly global, optimal solution would require repeated trials with different schedules, intensities, and priorities. If the potentia number of treatment types is large, including such types as planting intensity, thinnin fertilization, harvesting method, and species mix, finding a global solution may be extremely difficult.

Another limiting feature of the forest-wide simulation methods is the difficulty o introducing constraints into the analysis that might be applied to the harvest flow. Simulation models, however, can more readily identify feasible solutions than their optimization counterparts (Johnson and Tedder[1]).

OPTIMIZATION METHODS AT THE STAND LEVEL

Optimization methods for solving stand-level questions have long been used in forestry. Early methods of determining rotation length, such as maximum MAI and soil expectation were all optimization methods. These early methods were distinguished by the numerous assumptions made in order to solve them and by the amount of tedious calculations required. First applications of the electronic computer were aimed at solving the latter problem. More recently, mathematical programing techniques have made it easier to solve more complex problems and, therefore, reduce the need for numerous assumptions. A good example of this evolutionary process has been the development of optimization tools for jointly answering thinning plan and rotation length questions.

Optimal Thinning Plan and Rotation Length

Chappelle and Nelson (1964) presented an early solution to the joint optimization of thinning plan and rotation length in loblolly pine. They used volume growth equatio and marginal analysis to determine optimal volume stocking levels which would maximize net profit per annum. Then given an initial stocking level, the optimal stocking level and the volume growth model, they determined the volume to be removed by thinning in each cutting period for a fixed rotation length. Using this information and cost and revenue data, the optimal rotation length was determined using the classical soil expectation value method.

The solution computed by Chappelle and Nelson (1964) could be found by hand, but they computerized the process for ease of operation. While their method was advanced for its time, a number of assumptions or simplifications were made to reduce the comput tional load. First, the growth models were very simplistic. Second, the stumpage pric was assumed to be either constant over size of material or a linear function of stand age. Finally, costs that varied with stocking were not treated directly in their method (that is, stumpage was assumed to be net instead of gross).

In a later development, Amidon and Akin (1968) demonstrated how dynamic programin could be used to obtain the same solutions as Chappelle and Nelson (1964). Dynamic programing is a discrete mathematical programing tool that can describe a problem through a network of points. The number of "state" descriptors needed to define each point also defines the dimensions of the network. For example, Amidon and Akin define each point by its volume stocking, with 1,000 board foot intervals between points, and by its stand age, with 5-year intervals between points. Their network, therefore, had two state descriptors and was two dimensional.

The objective of dynamic programing is to find, within defined limits, the best or optimal path through the network. In the Amidon and Akin (1968) problem, therefore, the objective was to find the optimal stocking level at each age class. The limits of the network are defined by physical considerations such as maximum growth of the stand and the impossibility of negative volumes. Solution to the problem of finding an optimal path can be accomplished using either the forward or the backward recursive method.[2]

Because the forward recursive method is easier to understand, it will be explained first using the Amidon and Akin problem as an example. An initial stand age and stocking level are specified which defines the starting point in the network. A growth function is then used to advance the stand to one of the points in the next time period. If nothing were done the stand would remain at the stocking level of the point to which it had grown. Thinning, however, can reduce stocking which shifts the stand to other "lower" points in that time period. For the second time period, there is only one path the stand could have followed to get to each point because of the single starting point in the first time period. Because the second period has defined a number of points that the stand can grow from, there are a number of different paths in which a stand could arrive at a stocking point in the third time period. What is wanted, though, is the optimal path to that point. Therefore, all possible paths from one age to the next are examined and only information for the optimal path is stored for each possible stocking level at time period three. This process is continued for all stand age classes in the network.

The values that must be stored at every point in the network, excluding the starting oint, are the value of the objective function for the best path to that point and the oordinates of the previous point on the optimal path. With the forward recursion ethod, therefore, it is possible to examine all possible points at a given age and, sing the objective function value, determine the optimal stocking level for that age. iven that point, the optimal path (and therefore stocking level for each age) can be etermined from the stored coordinates.

Inherent in this method of determining the optimal path is the "principle of ptimality." Translated into the problem of determining the optimal thinning plan, this principle states that, once the optimal thinning plan has been determined to a pecified stand age and structure, the optimal plan for the next older stand age depends only on the older stand's age-structure combinations not yet analyzed. Thus, the various possible stand structures for a given age need to be analyzed only once, which greatly reduces the number of calculations necessary.

The backward recursion method ultimately provides the same answers as the forward recursion method, but the values stored at each point are different. The backward method starts at all possible ending points and determines the best path to the starting point. Stored at each point, therefore, is the optimal path to an ending point and the value of the objective function.

The advantage of the backward recursion method is that, if the stand should deviate from the optimal path due to insects, fire, or other problems, the network values already computed will show which new path is optimal to follow to the specified ending age. The disadvantage (and therefore the advantage of the forward recursion method) is that a new run must be made for each potential rotation length.

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[2] It is our belief that dynamic programing will prove to be a major analytical tool in the decisionmaking process. We also believe that it is probably a new and, perhaps, difficult tool to understand for many in our audience. Therefore, we have devoted proportionally more attention to it.

Amidon and Akin (1968) used the backward recursive method. They also greatly restricted the problem by allowing the stand to increase or decrease only 1,000 board feet in one growth period (this is, between adjacent age periods). This meant that a given point could only be reached from two adjacent points. While this reduced the complexity of the problem and made solution easier, it also greatly restricted possible thinning plans.

Because the backward recursive method solves for only one rotation length in a given run, Amidon and Akin (1968) had to make a number of runs to evaluate the effect of changing rotation length. Like Chappelle and Nelson (1964), they used the maximum soil expectation criterion for determining the optimal rotation length.

As pointed out by Amidon and Akin (1968), the advantage of dynamic programing over the marginal analysis approach of Chappelle and Nelson (1964) is its computational flexibility. Once the problem has been structured for dynamic programing, it is easy to change pricing and cost assumptions. Also, the results of one run can be used to evaluate other "suboptimal" solutions that might become viable if stand conditions change. A final computational advantage is that stand development models and dynamic functions need not be as simple as those used by Chappelle and Nelson (1964) and Amidon and Akin (1968).

After examining the approaches of Chappelle and Nelson (1964) and Amidon and Akin (1968), Schreuder (1971) made two critical comments on their methodology. First, he contended the four had ignored cost of land when determining optimal stocking levels. This omission, he said, can affect the determinination of economic stocking levels. Second, he felt that their method would not find the jointly optimal thinning plan and rotation length because their method "...does not consider the possible interdependenci of the period." Therefore, their method would ignore thinnings with negative value for the period but which, over the rotation period, could more than pay for themselves. Their method would also ignore timber selling costs, which vary with volume removed. Both of these factors could lead to suboptimal paths.

Schreuder (1971) proposed that thinning schedule, intensity, and rotation length could be easily optimized jointly if the final harvest cut were defined as an extreme thinning. He formulated the joint optimization problem in a continuous, control-theoretic form in which revenue, costs, rate of timber cut, stand yield, and growth were all functions of time. This formulation would determine the optimal thinning and quantity of volume removed in continuous, instead of discrete, values of time and volu Once he had the formulation, however, he discovered that an explicit solution could no be found except for trival problems. Schreuder (1971) then turned to the numerical solution method of dynamic programing to find a discrete solution to his formulation. Although he formulated the solution in a backward recursion, dynamic programing framework, he did not show actual examples of the process.

Practical application of dynamic programing to solve the joint optimization probl has recently been reported by Brodie and others (1978) and by Brodie and Kao (1979). In addition, Brodie and others (1978) demonstrated that, contrary to Schreuder's (1971 findings, the approaches of Chappelle and Nelson (1964) and Amidon and Akin (1968) do indeed simultaneously solve for both optimal stocking level and rotation length.

The purpose of the Brodie and others (1978) study was to assess the "impacts of regeneration cost, initial stocking level, site, quality premiums, and variable loggin costs on thinning and rotation...." Three features distinguish this dynamic programin formulation from that of Amidon and Akin (1968). First, the stand model used by Brodie and others (1978) incorporates a mortality estimator. More realistic estimates of the effects of thinning, through mortality capture, therefore, can be made and evaluated.

Second, the dynamic network of Brodie and others (1978) allows much greater accuracy in defining thinning intensity than did Amidon and Akin's (1968) network. From any specified node, the latter's network allowed the stocking level to either increase or decrease 1,000 board feet. Brodie and others (1978) allow stocking to decrease by 100 cubic foot increments to zero and to increase by 100 cubic foot increments to maximum potential stockings for the age class.

Finally, Brodie and others (1978) chose to use the forward recursion method instead of the backward as advocated by Amidon and Akin (1968) and Schreuder (1971). For thinning analysis, they considered the forward method a more flexible tool than the backward method.

One shortcoming that Brodie and others (1978) identified with their approach was that the stand model did not provide diameter growth acceleration usually expected from thinning. If quality premiums are important, this shortcoming can lead to suboptimal solutions.

The most recent work in the application of dynamic programing to stand problems, by Brodie and Kao (1979), eliminates this shortcoming. They accomplished this by sing a much more complex stand model that incorporates growth acceleration in the uadratic mean stand diameter. After a careful examination of the stand model, Brodie and Kao (1979) found that the model could be initialized for a specified site index if the three values of stand age, basal area, and number of trees were known. These ariables, therefore, formed the three state descriptors for the dynamic programing solution. The sizes of the intervals between nodes are 10 years, 4 square feet of basal area, and 15 trees, respectively.

Analysis results using the three-descriptor framework are the optimal number of trees and basal area to maintain in each time interval. To obtain these values, Brodie and Kao (1979) used the forward recursion solution method. Because quadratic mean tand diameter can be computed from number of trees and stand basal area, stumpage prices and logging costs could be more realistically introduced into the anaylsis as unctions of quadratic mean stand diameter.

Other Possible Methods of Determining Optimal Thinning Plan and Rotation Length

The dynamic programing approaches reported to date have all ignored or assumed a diameter distribution structure. Diameter distribution data is important, however, in the planning of milling facilities and as an aid in applying specified treatments to field conditions. Therefore, a procedure that can determine the optimal number of trees for each time period by diameter classes may have greater usefulness than present procedures.

Conceptually, dynamic programing can also be used to determine optimal diameter class distributions over time. The state descriptors would be number-of-trees classes (T) in one of the Dth diameter classes at one of the Ath age periods. As a result, the number of dimensions for the network space is D+1 and the number of nodes in the network is $A(T_c)^D$. From these formulas, it is easy to see how the theoretically possible first becomes impossible in practical applications. Suppose, for example, the task was to determine, within 10 trees per diameter class, the optimal number of trees to maintain in each 2-inch diameter class at the start of each 10-year period. Further, suppose that the maximum number of trees per diameter class was 250, the maximum stand age was 120 years, and the maximum diameter class size was 40 inches, then the number-of-trees classes would be 26 (0, 1-10, 11-20, ..., 241-250), the number of ages 12 (10, 20, ..., 120), and the number of diameter classes 20 (2, 4, ..., 40). Using these values, the number of dimensions for the network space would be computed as 20+1=21, and the number of nodes in the network would be $12\times26^{20} = 3.12\times10^{22}$.

Discussion in this section has been confined to deterministic analysis of stand-level questions. Stochastic stand-level decision analysis using dynamic programing is presented in several papers (Hool 1966, Lembersky and Johnson 1975; Lembersky 1976).

Another potentially promising approach has been described by Adams and Ek (1974). Part of their work dealt with the problem of converting an existing uneven-aged diamet distribution to a targeted structure over a number of time periods in which cutting could occur. This problem is analagous to the even-aged situation of starting with a specified stand, growing, and thinning it over a number of time periods until a targ diameter distribution of zero trees in each diameter class is reached in the last time period. Adams and Ek (1974) used a nonlinear programing approach which necessitated a relatively simple stand model that explicitly predicted the net change in number of trees in a diameter class. Their method was also limited as to the number of time periods over which the method could be applied.

It is obvious that methods for determining what diameter distributions are optima to carry over time are in their infancy. Alternatives to dynamic or nonlinear programing, such as application of optimal control theory or decomposition theory, have been suggested (Adams 1974 and Adams and Ek 1976), but the development and tesing of practi applications is limited.

Optimal Fertilization Plan and Species Mix

Fertilization and species mix are two additional factors which can interact and affect optimal thinning plans and rotation lengths. Consequently, they should all be jointly optimized to reflect their interdependencies. It has already been shown how an optimal thinning plan, and rotation length can be jointly determined for a stand. The problem now is the incorporation of fertilization and species mix into the proces

The optimization of timing and intensity for fertilization has not been addresse in the literature. This is explained by the scarcity of stand models with built-in fertilization response functions. Once appropriate stand models have been developed, the joint optimization of thinning schedule and intensity, rotation length, fertiliza schedule, and intensity can be done using dynamic programing. Incorporation of ferti zation intensity results only in a mulitiplicative increase in computations and not a exponentiation of network size,[3] provided that entry-time intervals are longer than t effect of fertilization.

Species mix is another area where little work has been reported. As with fertil zation, one reason for this is the dearth of stand simulators that can handle multipl species. Given a multiple species stand model, optimization could be done by use of dynamic programing. An additional state descriptor would be required for each specie in the problem.

Evaluation of Optimization Methods for Answering Stand-Level Questions

CHARACTERIZATION OF THE STAND

As with the stand-level simulation methods, all stand-level optimization methods characterize the stand by those features used to initialize the particular stand development model type used by the optimization methods.

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[3] Kao, Chiang. 1980. A study of optimal timing and intensity of silvicultural practices--commercial and precommercial thinning, fertilization, and regeneration effort. Ph.D. diss. Dep. of For. Manage., Oreg. State Univ., Corvallis. 219 p.

GROWTH AND YIELD INFORMATION

Stand-level decision using dynamics programing can be applied to any type of stand development model, if it is acceptable to the manager to prespecify thinning rules (such as, cut smallest or largest trees first) for priority of removals (Martin 1978). If this condition is not acceptable, then application of dynamic programing is currently limited to the whole-stand/diameter-free type of stand development model.

Analyses using nonlinear programing, and perhaps control theoretic techniques, are potentially applicable to the whole-stand/diameter-class type of stand development model.

COMPUTATIONAL BURDEN

In application of dynamic programing, size of the problem can cause difficulties and pose limitations. For example, if a stand simulator existed that was initialized by number of trees and basal area for any of a number of species and if A is the number of age classes, T is the number of tree classes, B is the number of basal area classes, and S is the number of species, then the dimensional size of the dynamics programing network space would be 2S+1 and the number of nodes would be $A\cdot(B\cdot T)^S$. Thus, problems of this type become large very fast and, if a diameter class distribution type of simulator were used, the size of the problem is increased many fold (that is, using these and the previously defined symbols, size of the network space would be SD+1 and number of nodes would be $A\cdot T_c^{S\cdot D}$).

Another limitation of optimization methods is the size of their computer programs. This problem is particularly aggravated if the optimization method is interfaced with some of the complex stand development model types.

FLEXIBILITY OF THE SOLUTION SPECIFICATION

Both the dynamic programing and the nonlinear programing methods can determine the optimal treatment plan to follow to meet both physical and economic management objectives.

OTHER CONSIDERATIONS

As a precaution, the "principle of optimality" that is inherent in dynamic pro-raming is a restriction that must be dealt with carefully. It has been previously hown how a model that characterizes stand development by site index, age, basal area, and number of trees per acre can be used to determine optimal thinning plans by the dynamic programing technique. Because the time variant variables (age, basal area, nd number of trees) were all state descriptors, the "principle of optimality" can be et. If additional variables are used in the model, then one of three actions can be taken to still meet the principle. First, the additional variables can be added to the analyses as additional state descriptors. This is the most obvious and theoretically est solution, but, as demonstrated, it comes at the potentially high or impossible equirement of larger computer capacity.

The second method of handling additional variables is to make assumptions about he relationship between the additional variable(s) and the state descriptors. This as the method used by Martin (1978). Finally, for some variables, it is possible to void the problem by modifying the existing state descriptors. Suppose, for example, hat additional variables (such as time since last cutting or time since fertilization) ave been used to explain variation not explained by the state descriptors (such as residual basal area and/or number of trees). If the effect of these variables becomes zero after a period of time, then these variables can be handled, without introducing additional state descriptors, by defining the planning period length to be at least as ong as or longer than the period it takes for the effect to disappear.

OPTIMIZATION METHODS AT THE FOREST LEVEL

Over the past two decades, a considerable amount of effort has been directed at developing techniques for answering forest-wide management questions. An excellent evaluation, analysis, and summary of most of these techniques has been provided by Johnson and Scheurman (1977). They defined two basic mathematical programing formulations, which they called Model I and Model II, and two pricing options. The two basic formulations differ by their treatment of the stand classes. For the sake of simplicity Johnson and Scheurman (1977) assume that the forest is composed of one species and one site quality and that the resulting forest structure can be adequately portrayed by age classes.

With this forest structure, Model I defines a management unit by its initial age class and these units are maintained throughout the analyses. Therefore, only one set of activities consisting of a number of alternative treatment plans must be defined for each management unit. A treatment plan is defined by the timing of harvest and thinning cuts and the resultant returns expected across the entire planning horizon. The optimal solution is characterized by the number of acres in a management unit assigned to each treatment plan in order to meet management objectives and constraints.

Model II also defines starting management units by their initial age classes. New management units, however, are defined if harvesting of the initial age classes occurs (that is, if harvesting occurs in several different age classes during a period, then all acres harvested are combined into a new management unit). As a result, management units are not fixed for the entire analysis.

For Model II, a number of activity sets, or treatment plans, must be defined. A first set of activities defines for the initial management units the returns from all possible timings of the first harvest cut or of the return at the end of the planning horizon if the units are never harvested. A second set of activities defines for management units that have been cut and defined due to first harvesting all possible timings of the second harvest cut or of the returns at the end of the planning horizon if the units are never reharvested. The required number of sets of activities of this type is equal to the maximum number of harvest cuts that can be made in the planning horizon to a single stand class.

While only one set of activities is needed for the Model I formulation, Johnson and Scheurman (1977) have shown that the number of activities in this set could greatly exceed the total number of activities in all of the sets of the Model II formulation. On the other hand, Model II requires more area constraints than the Model I formulation. Area constraints guarantee that the area harvested is no greater than the area within an age class in any period. Nonnegativity constraints guarantee that harvest volumes and areas from a class are not negative. Other constraints, such as harvest volume control constraints, can also be incorporated in the analysis if needed to meet manageri objectives. The number of harvest control constraints are the same in either formulation. The preceding emphasis on the number of activities and constraints needed by each model to formulate a solution is because of the concern that the resulting formulations do not exceed computer limitations.

Linear Programing

As mentioned earlier, each formulation for solving the optimum scheduling of stands n the forest can have two pricing options if the objective involves an economic riterion. The first, and historically the most widely used, option is founded on the rinciple that for a given stand class, treatment plan, and planning period, the unit rice received is constant regardless of the volume cut. If this assumption is cceptable, the operations research technique of linear programing can be applied to olve both the Model I and the Model II formulations. The works of Loucks (1964), Navon 1971), and Ware and Clutter (1971) represent the application of linear programing to olving Model I formulations. In their review, Johnson and Scheurman (1977) demonstrated ow the simulation techniques of the area-volume check method, SORAC (Chappelle 1966) nd SIMAC (Sassaman and others 1972) could all be reformulated into different forms of odel II. They also showed how Nautiyal and Pearse's (1967) formulation for solving he optimal even-aged conversion problem could also be formulated as another form of odel II.

Mathematical Programing Techniques for Quadratic Objective Functions

The second pricing option assumes that for a given stand class, treatment plan, ad planning period, the unit price received for an acre cut is a function of the volume ct, and the form is one that declines linearly as the acreage cut increases. If this asumption is acceptable and reasonable, then, theoretically, the operations research tchnique quadratic programing can be applied to solve both basic formulations. A lmited and specialized algorithm form has also been developed that incorporates the qadratic objective function. The first example of this algorithm form was Walker's (976) ECHO (Economic Harvest Optimization Model), which Johnson and Scheurman (1977) rported to be a special formulation of Model II. A revised form of this algorithm i incorporated in TREES (Tedder and others 1980). Hrubes and Navon (1976) have aproximated the ECHO solution using separable linear programing.

Goal Programing

Both Model I and Model II pertain to management programs that are concerned with sngle objectives such as maximization of volume production or of present net worth. Fr programs that are concerned with multiple objectives, the historical approach has ben to pick one of them for optimization and treat the rest as constraints. In the aea of multiple objective optimization techniques, goal programing has received some atention in forest related problems. Kao and Brodie (1979) have looked into the use o goal programing for scheduling the treatment of all stands within the forest. They emined the problem of maximizing present net worth (objective 1), of maintaining an evn-flow of harvest (objective 2), and of producing a regulated forest structure at th end of the planning horizon (objective 3). In another study, Field and others[4] hae demonstrated the trade off of maximizing volume while maintaining nondeclining evnflow on a southern forest.

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[4] Field, Richard C., Peter E. Dress, and James C. Fortson. Complementary linear an goal programing procedures for timber harvest scheduling. For. Sci. [in press].

Goal programing is an extension of linear programing. The objective of goal programing is to minimize the weighted difference between the targeted value for each objective and the feasible value of each objective. The weights of priorities assigne to each objective are specified by the analyst and can be changed between runs to evaluate their influence upon the solution. Using a simple example, Kao and Brodie (1979) demonstrated that goal programing could produce reasonable, compromise solution to problems with infeasible linear programing solutions due to conflicting objectives.

Integer Programing

Both linear and goal programing can result in the acreage of a stand class being assigned to a number of alternative treatment plans. If it is desired that a stand class be assigned only one treatment plan, the appropriate optimization tool is either integer or integer-goal programing. To date, the computational limitations of these tools have precluded their widespread application to practical forestry problems (Bare and Norman 1969). Recent developments in optimization technology (Glover and others 1978), however, may provide for wider use of integer programing in the future.

Evaluation of Optimization Methods for Answering Forest-wide Questions

CHARACTERIZATION OF THE FOREST

In the forest-wide optimization methods, forests are usually characterized by ver simple structures based on gross stand class aggregates. Aggregating stands in this fashion could cause problems in accurately predicting treatment plan responses because stand development models are usually nonlinear in form.

The disadvantage of having to aggregate stands has risen out of the need to minim problem size so that solutions are computationally feasible, that is, the fewer stand classes, the smaller the problem. There is, however, another feasibility problem whic may conflict with the objective of reducing problem size by defining few stand classes When constrained optimization is used, it is often found that a large number of altern treatment plans must be defined for each stand class in order to find an operationally feasible solution.

As an alternative to this historical approach, it seems equally possible to defin a large number of more homogenous stands (or if need be, stand classes) and a few alternate treatment plans for each. These alternate treatment plans could be develope by determining the optimal treatment plan for several different rotation lengths. The choice of rotation lengths could be made through an intelligent examination of existin forest structure problems and by determining where resulting future yields may be most lacking. This approach would produce more defensible yield predictions, provide a link between stand level and forest-wide optimization, and would tie treatments to the basic management unit, the stand. Testing this approach for feasibility seems justifi

Problems associated with this disadvantage may be further minimized (or even eliminated) by the recent development of a new method for solving linear programing problems (Kolata 1979). This new technique is reportedly capable of solving much larger problems in shorter time periods than the currently used simplex method.

GROWTH AND YIELD INFORMATION

The yield information for all of the forest-wide optimization methods is tabular in form. Therefore, any source of yield information can be utilized. As with the forest-wide simulation methods, thinning yields can be credited to the total harvest when they occur instead of at the final regeneration harvest cut.

COMPUTATIONAL BURDEN

Forest-wide optimization methods usually take longer computer times to operate than their simulation counterparts (Johnson and Tedder[1]). Recent advances (Kolata 1979), however, may minimize or eliminate this disadvantage.

FLEXIBILITY OF THE SOLUTION SPECIFICATION

All forest-wide optimization methods can evaluate both physical and economic objectives. Some of the advantages of optimization methods include:

1. Alternative treatment plans for each stand class can be evaluated in one run and an optimal plan determined.
2. Cutting priorities do not need to be specified nor assumed.
3. Complex constraint specifications can be incorporated into the analysis.
4. Solutions can usually be generalized because first order optimization conditions are stated or implied in the analysis method.

Finding feasible solutions, however, is often more difficult with optimization methods than with simulation methods (Johnson and Tedder[1]).

OTHER CONSIDERATIONS

In many of the optimization methods, fractionization of stands can occur by assigning more than one treatment plan to the stand. The use of integer programing is a possible future solution to this problem.

SIMULTANEOUS, OPTIMAL SOLUTION OF THE STAND- AND FOREST-LEVEL QUESTIONS

If a perfectly regulated forest structure exists or if harvest-level constraints are not important, then the joint optimization of stand and forest-level questions can e computed easily by determining each stand's optimal treatment plan and aggregating across the whole forest. Unfortunately, these conditions seldom exist and the manager s left with the problem of trying to determine suboptimal stand treatment plans that ill meet forest-wide objectives and constraints.

Work on this joint optimization problem has only recently received some attention. illiams (1976) and Nazareth (1973) independently demonstrated an approach for joint optimization using an extremely simple forest structure. They found that it is the ize of the joint optimization problem and not its structure that leads to solution ifficulties. Many of the linear-programing harvest scheduling studies discussed above rovide for optimization over several stand-level treatments. The dynamic programing olutions discussed above indicate a large, finite number of stand-level treatments. single, large linear programing formulation, incorporating all of these stand-level reatments as activities, would be unmanageable in size. The problem is solvable, owever, by decomposition--a process by which large linear programing problems can be rtitioned into smaller problems whose solutions can be aggregated to provide the olution to the orginal large problem.

For the joint stand-level and harvest scheduling problem, the process is describ as follows:

1. Solve the dynamic programing stand-level treatment network to find the optim stand-level treatment sequence and the optimal sequence of treatments for ev other potential stand condition. A large number of potential stand treatmen activities are thus defined.

2. Enter the optimal sequence of stand-level treatments as activities in a constrained linear programing harvest scheduling problem and solve for the optimum harvest schedule. This solution is usually not the optimum harvest schedule over all possible stand-level treatments as there are probably nonoptimal stand-level treatments that enhance the constrained objective functi For example, heavier than optimal thinning or early final harvest can provid volume in periods where available volumes from the optimal stand solutions a constraining.

3. A decomposition is performed whereby new activities are selected using infor mation from the first solution as a starting point. A new optimum harvest schedule is formed using these activities.

4. Successive decompositions are performed with the process terminating after a prespecified number of decompositions or when the objective function enhance ment between decompositions is trivial.

Because this joint optimization technique combines both dynamic and linear programing, it also exhibits their strengths and weaknesses. This technique has been used to jointly determine the optimal thinning plans, rotation lengths, and the harve ing schedule for a forest of simple structure and a single species (Nazareth 1973; Williams 1976). While theoretically feasible, incorporation of optimal fertilization plans, species mixes, and diameter distribution for more complex forest structures ha not yet been demonstrated. The recent advance in linear programing technology (Kolat 1979) may, however, eliminate the need for decomposition to solve this or even more complex problems. In any case, the linear programing portion of the method still wou cause the fractionalization of stands (classes).

SUMMARY

The assignment of the best (or optimal) treatment plan to every stand in the for during each planning period is the basic decision each forest manager must make. His ically, this basic decision was made by partitioning it into several separate decisio For even-aged management, these subordinate decisions have included the optimal plant density, thinning plan (and resulting diameter distributions), rotation length, fertilization plan and species mix for each stand, and the optimal schedule of stand treatments for the entire forest.

A number of optimizing and nonoptimizing decisionmaking tools have been develope to handle singly or jointly the planting density, thinning plan, and rotation length decisions at the stand level. While improvements in making these particular decision might be possible using nonlinear programing, the quality of decisions now possible from existing tools appears adequate at this time. Stand-level decisions concerning optimal diameter distributions, fertilization plans, and species mixes, however, have not received adequate attention. Growth modeling limitations appear to be the major factors holding back development in this area.

At the forest level, a number of tools have also been developed to help in making stand treatment scheduling decisions. Additional research on the usage of integer programing to schedule entire stands and on the development of multiple objective optimization techniques would provide even greater analytical flexibility to the decisionmaker.

Finally, a technique for the simultaneous consideration of both stand-level and forest-wide decisions has recently been developed and reported (Nazareth 1973; Williams 1976). Expansion of this technology to include optimal diameter distributions, fertilization plans and species mixes for multiple objectives should ultimately lead to the solution of the basic managerial decision.

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GLOSSARY

Allowable cut - The amount of timber that can be removed in a planning period if the optimal schedule of stand treatments is fully applied to the forest.

Allocation problem - The task of distributing limited resources to alternative uses.

Area constraints - Constraints imposed in mathematical programing formulations to lim area harvested. A set of real area constraints is necessary to limit area harve from an age class to an amount less than or equal to the area in the age class.

Area control - A classical harvest scheduling technique that achieves a regulated forest in one rotation by harvesting equal areas in each time period. A variant of the method achieves constant equilibrium harvests by harvesting areas of cons long-run productivity during the conversion period. Area control stabilizes the area harvested during the conversion period, but volume harvest will fluctuate, dependent on the initial age class distribution.

AREA - An algorithm (Sassaman and Chappelle 1967) for computing allowable cuts using the area control method.

Area-volume-check - A repetitive classical harvest scheduling technique that attempts to resolve conflicts between volume, area, and time period of harvesting over th forest. An initial volume estimate of harvest is applied to the forest area and age-class distribution and the resulting areas harvested. Length of time for cutting the whole forest is then checked and if found unsatisfactory, the initia estimate is adjusted upwards or downwards until volume, area, and cutting time are judged satisfactory.

ARVOL (*AR*ea *VOL*ume) - An algorithm (Chappelle 1966) for computing allowable cuts duri the conversion period using the area-volume method.

Backward recursion - A dynamic programing solution strategy that starts with the olde stand age (the rotation age of the stand) and solves the optimal treatment plan to the youngest stand age. The advantage of the backward recursion method is th if the stand should deviate from the optimal path, the network values already computed will show which new path is optimal to follow to the specified ending a The disadvantage is that a new run must be made for each potential rotation leng

Binary search - A technique for meeting objectives and constraints of a specified problem by repeated solutions until a feasible maximum or minimum solution is fo Approach is usually specific to a particular, rather than general problem specifi cation. Binary search involves an efficient technique of identifying upper and lower bounds for the solution of each iteration and using the midpoint for the next iteration trial until a tolerance between upper and lower bound is met.

Control theoretic optimization - A group of mathematical programing problems consist of optimizing a set of control variables such as levels of thinning, timing of these thinnings, and final harvest. Techniques used are usually nonlinear progr ing or dynamic programing.

Conversion period - The length of time required to apply the conversion strategy. Harvest volume may fluctuate during the conversion period if inventory must be accumulated or depleted to reach the fully regulated condition.

Conversion strategy - A treatment plan designed to convert a forest from its present structure to a targeted structure.

Decomposition (Dantzig-Wolfe decomposition) - A process by which large linear programing problems can be disaggregated to provide the solution to the original large problem.

Deterministic analysis - Analysis conducted under the assumption that variables are single valued (that is, not governed by a probability distribution).

Diameter distribution schedule - A schedule for the number of trees by diameter class for each planning period.

Dynamic programing (DP) - a technique for solving mathematical programing problems using discrete numerical computation rather than simultaneous solution of continuous functions. Used in forestry for simultaneous solution of thinning plan and rotation length, and for other allocation problems.

CHO (*EC*onomic *H*arvest *O*ptimization) - An algorithm (Walker 1976) that uses a binary search technique for maximizing the present net worth of harvest schedule under the assumption of a downward sloping demand curve. The solution approximates a quadratic programing solution with specialized restrictions.

easible solutions - Any solution that satisfies all objectives and constraints in a problem specification. The optimal solution is the maximum or minimum valued feasible solution.

ertilization plan - A program of fertilization that incorporates both the scheduling and the intensity of fertilization.

orward recursion - A dynamic programing solution strategy that starts with the youngest stand age and determines for each possible rotation length over the planning horizon the optimal treatment plan for each rotation length. The advantage of the forward recursion method is that optimal treatment plans for all rotation lengths are determined in one run. In addition, its method of handling the growth of stands makes it easier to adapt stand development models to a dynamic programing formulation.

oal programing (GP) - A technique for solving mathematical programing problems with multiple objectives and goals by minimizing the deviations from the goals. Two uses in forestry have been to determine compromise solutions for both multiple uses or harvest scheduling objectives.

arvest scheduling technique - A method for determining when individual stands or stand classes should be thinned or final harvested in order to meet the forest owner's objectives.

teger programing (IP) - A technique for solving mathematical programing problems where the variables are constrained to take integer values. Used in forestry for harvest scheduling problems where complete stands must be assigned to a particular treatment plan use.

inear programing (LP) - A technique for solving mathematical programing problems in which the objective and constraint variables are linear. Used in forestry for solving resource allocation and harvest scheduling problems.

L activities - A set of treatment plans that can be applied to a specified management unit.

LP constraints - Specified relationships that guarantee that a problem solution meets both the conditions desired (or imposed) by the manager and conditions necessary to meet the problem specification. (See Area constraints, Nonnegativity constrai and Volume constraints for specific examples.)

Management unit - A group of stands usually defined by their initial stand age.

Marginal analysis - Analysis based on the economic optimization principle that margina revenue should equal marginal cost, where marginal revenue is defined as the contribution to revenue of an additional unit produced and marginal cost is defi as the contribution to cost of an additional unit of production. So long as additional production contributes more to revenue than cost, production should b expanded.

Mathematical programing - A body of optimization techniques for solving problems with functionally specified objectives and constraints. The maximum or minimum value of the objective is found by a defined process in a finite number of steps. (Se Linear programing, Goal programing, Integer programing, Nonlinear programing, Quadratic programing, and Dynamic programing for specific examples.)

Maximum forest rent rotation - The rotation for which average annual revenue minus cost is greatest. As an economic criterion for determining rotation length, thi method has been strongly criticized for ignoring the opportunity cost incurred b locking up capital in forest investment.

Maximum MAI (*M*ean *A*nnual *I*ncrement) Rotation - The rotation for which volume divided by age is maximum. This rotation provides the greatest physical yield in the lo run.

Maximum present net worth rotation - The rotation for which discounted revenue minus discounted cost is greatest evaluated on a single rotation basis. When used as a criterion, land value is implicitly zero and rotation is longer than the maxim soil expectation rotation.

Maximum soil expectation rotation - The rotation for which discounted revenue minus discounted cost is greatest evaluted on the basis of an infinite series of rotations. This criterion values land at its maximum value in even-aged forest use for given species, prices, costs, and discount rate. The rotation is shorte than an evaluation based on a single rotation.

Model I - A mathematical programing formulation for harvest scheduling in which the identity of the initial management units (or stand classes) is maintained throug out the analysis. Through use of a Model I formulation, management planning decisions are easily tied to the ground. Model I formulations have many activit and few constraints when compared with the comparable Model II formulations.

Model II - A mathematical programing formulation for harvest scheduling in which acre in initial management units are reclassified and aggregated into new management units as they are harvested. Model II formulations have fewer activities and more constraints than the comparable Model I formulation.

Network - Many dynamic programing problems are characterized as two or more dimension graphs (networks). Even-aged stands can be characterized as developing in a graphical space characterized by: volume and age, volume and basal area or volum age, and basal area. The number of variables (state descriptor variables) defin the dimensions of the network. Dynamic programing analysis is undertaken using discrete intervals within the network.

Nonlinear programing (NLP) - A body of techniques for solving mathematical programing problems in which the objective and constraint variables are nonlinear. Used in forestry to determine uneven-aged diameter distribution schedules, conversion schedules for uneven-aged stands, and thinning plan and rotation age for even-aged forests.

Nonnegativity constraints - Constraints imposed in mathematical programing formulations to limit variables to zero or positive values because negative volumes or acres harvested are infeasible and have no meaning in the usual problem specification.

Normal yield tables - Tables that present, by site index, and stand age, the yield of "fully stocked," undisturbed natural stands.

Optimal solution - A solution which best, or most favorably, meets the specified objectives and constraints of management.

Planning horizon - The total number of planning periods in an analysis.

Planning period - The shortest time period (usually in years) of concern in an analysis. One-, five-, and ten-year planning periods are common.

Principle of optimality - The fundamental principle on which dynamic programing is based. The principle states that once the optimal path through the dynamic programing network has been determined from the initial state to a specific state, the optimal path through the remaining stages of the network depends only on the portion of the network not yet analyzed. The principle of optimality allows a great reduction in the amount of necessary calculations.

ure simulation - A technique for examining the consequences of applying a set of management decisions and/or rules to a stand or forest. Alternative management decisions and/or rules can be examined through repeated application of the simulation process.

uadratic programing - A special case of nonlinear programing in which the objective function is a quadratic form.

egulated forest (even-aged) - Strictly defined, a forest with a stand age class distribution such that the area in each age class from age one to rotation age is equal to the total area of the forest divided by the rotation age. If this forest is harvested on an annual basis at the rate of area/rotation age, the yield and age-class structure will remain constant over time. The term in practice is applied to forest age-class distributions that are approximately uniformly balanced so as to approximate the above equilibrium conditions.

Rotation length - The period of time elapsing between the time a stand is regenerated and the time it is final harvested. Applicable to the even-aged management system.

SIMAC (*S*imulated *I*ntensively *M*anaged *A*llowable *C*ut) - An algorithm (Sassaman and others 1972) for computing the allowable cut over the planning horizon using binary search techniques. Age related cutting priorities, fixed allowable cuts (for the first ten decades), and an upper and lower bound on the allowable cut can all be specified by the user.

Single-tree/distance-dependent model - A stand development model that characterizes the stand by a plot composed of individual tree measurements, including tree coordinates. Using the tree coordinates, an individual tree's competitive status within the plot is computed by examining the nearness and size of surrounding trees. Models of this type have been developed for even-aged and uneven-aged, pure and mixed species stands.

Single-tree/distance-independent model - A stand development model that characterizes the stand by a representative sample of individual tree measurements. Because t coordinates are not used, a tree's competitive status within the stand is characterized by comparing the tree's size to all other trees in the stand or sample. Models of this type have been developed for even- and uneven-aged, pure and mixe species stands.

SORAC (*S*h*O*rt *R*un *A*llowable *C*ut) - A binary search algorithm (Chappelle and Sassaman 1968) for computing the allowable cut using area control, area-volume check, or both. The area control option provides greater flexibility than algorithm AREA, while the area-volume check method has incorporated into it a dynamic look-ahead feature which was not in ARVOL. The dynamic look-ahead feature simulates the continual updating process normally associated with timber management planning.

Stand class - An aggregation of stands of similar species mix, site quality, and age into a common class.

Stand development model - A mathematical model (often coded for computer use) that predicts the development of the tree component of a stand over time. Ideally, a stand development model should incorporate components for: gross growth, non-catastrophic mortality, regeneration, catastrophic losses, the introduction of managerial decisions, and the portrayal of the prediction result. (See Whole-stand/diameter-free, Whole-stand/diameter-function, Whole-stand/diameter-class, Single-tree/distance-dependent, and Single-tree/distance-independent models for definitions of the various types of stand development models.)

State descriptors - A set of variables that uniquely characterize a condition (state) that a system may be in. It is used in dynamic programing analysis where even-a stands are characterized by two-descriptors (age and volume or age and basal are or three descriptors (age, basal area, and number of trees).

Stochastic analysis - Analysis conducted under the assumption that variables can take one of several values with known probability (that is, governed by a probability distribution).

TEVAP2 (*T*imber *EV*aluation *A*nd *P*lanning *2*) - A pure simulation algorithm (Myers 1974) for examining alternative allowable cut strategies over a single planning period The algorithm projects individual stands under prespecified treatment plans as a basis for allowable cut determination.

Thinning plan - A program of thinning that incorporates both the scheduling and the intensity of thinning.

Treatment plan - A program of treatment(s) that incorporates both the scheduling and the intensity of application.

TREES (*T*imber *R*esources *E*conomic *E*stimation *S*ystem) - A package of binary search techniques (Tedder and others 1980) which incorporates the alternatives of area cont volume control, SIMAC, SORAC, or ECHO type approaches. When compared to these other algorithms, TREES has been designed to provide a higher degree of flexibil for solving harvest scheduling problems.

Volume constraints - Constraints imposed in mathematical programing formulations to limit volume harvested in each period.

Volume control - A classical formula based harvest scheduling technique that uses forest volume growth, inventory or age class data in various combinations to determine conversion period allowable harvest. Volume harvested under this method will be constant for the planning period, but area harvested will vary depending on the initial age-class distribution. Formula results are gross approximations which were usually adjusted using area-volume-check techniques.

Whole-stand/diameter-class model - A stand development model that provides average stand information by characterizing the stand as the number of trees in defined diameter classes (that is, dividing the stand diameter distribution into classes and predicting the number of trees in each class). Models of this type can be developed for even- or uneven-aged, natural or managed stands of pure or mixed species. They are initialized by site index, number of trees by diameter classes, and, perhaps, by additional stand variables such as stand age.

Whole-stand/diameter-free model - A stand development model that provides average stand information, but does not provide diameter distribution data. Models of this type are usually for pure, managed or natural even-aged stands, and are initialized by site index and stand values such as stand age, average or quadratic diameter, and the basal area or total number of trees in the stand.

hole-stand/diameter-function model - A stand development model that provides average stand information through the use of smooth functions, such as the Weibull or beta distribution functions, to characterize the diameter distribution. Models of this type have usually been limited to pure unmanaged even-aged stands and are initialized by site index and stand age.

Hann, David W., and J. Douglas Brodie.
1980. Even-aged management: basic managerial questions and
available or potential techniques for answering them.
USDA For. Serv. Gen. Tech. Rep. INT-83, 29p. Intermt.
For. and Range Exp. Stn., Ogden, Utah 84401.

Major stand-level and forest-wide decisions facing forest managers interested in applying even-aged management are identified. Traditional, current, or potentially useful techniques for making these decisions are reviewed. Emphasis is placed upon the way each method characterizes the stand or forest, the growth and yield information requirements of each method, the computational burden associated with each method, and the flexibility of each method and its adaptability to the form and complexity of the solution.

KEYWORDS: even-aged, forest management, management decisions, stand modeling, mathematical programing, optimization, simulation, harvest scheduling.

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PACT OF BACKCOUNTRY RECREATIONISTS
WILDLIFE:
ANNOTATED BIBLIOGRAPHY

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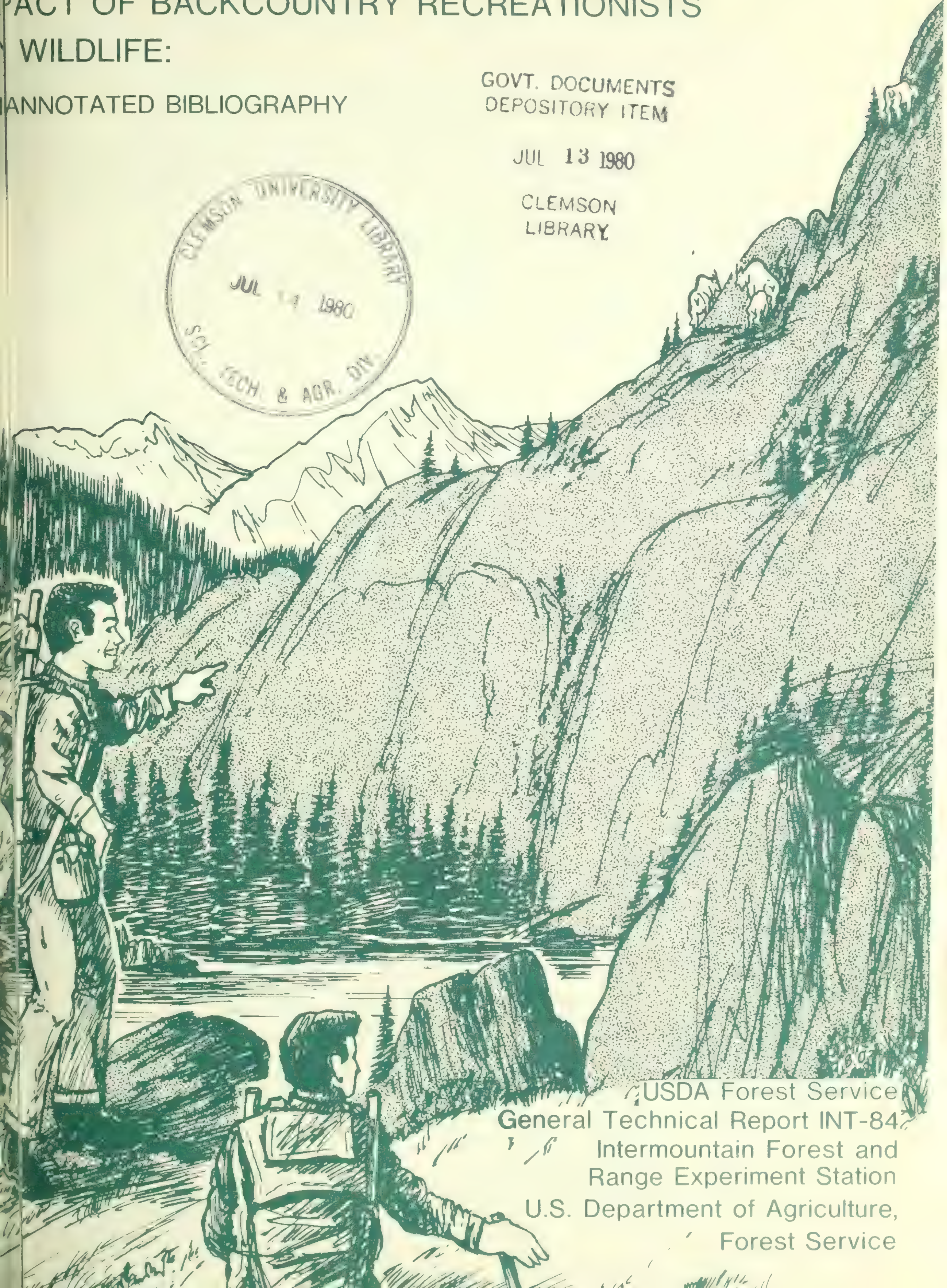

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THE AUTHOR

CATHERINE H. REAM researched this publication while on intergovernmental loan from the University of Montana Forestry School to the Wilderness Management Research Work Unit at the Forestry Sciences Laboratory in Missoula, Montana. Dr. Ream has done field work and published on reptiles and birds, and has participated in research on the vegetation of the Boundary Waters Canoe Area, wolves in northeastern Minnesota, and elk in Montana. Dr. Ream has her B.S., M.S., and Ph.D. degrees in zoology, with a plant ecology minor from the University of Wisconsin, Madison.

RESEARCH SUMMARY

An annotated bibliography and evaluation of the literature on the effects of backcountry recreationists on wildlife. Literature was taken from biological, managerial, sociological, and popular publications. Orientation includes descriptions of impacts and methods of reducing impacts of recreationists on wildlife.

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IMPACT OF BACKCOUNTRY RECREATIONISTS ON WILDLIFE:

AN ANNOTATED BIBLIOGRAPHY

compiled by

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INTRODUCTION

The impact of recreationists on backcountry resources has increased as the numbers recreationists have grown and the quantity of wildlands has decreased. Recreational acts on campsites, trails, and vegetation have frequently been documented.[1] ever, the effect of backcountry recreationists on wildlife has been given less ention, probably because most wildlife species are not fixed to the spot (as are nts) and, therefore, recreational effects are not immediately evident.

Outdoor recreation is increasing at a greater rate than the national population. kcountry areas that previously were virtually unknown to recreationists are now eiving steady traffic. Roading, logging, mining, resorts, and other forms of elopment compound impact problems by reducing wildlife habitat. People are erested in seeing and photographing wildlife, including highly vulnerable wildlife h as nesting birds, wintering ungulates, and whales on calving grounds. Hikers crosscountry skiers are invading wildlife habitat in numbers that have caused dlife to cease using otherwise desirable habitat. This is particularly true in as where hunting is allowed. Animals conditioned to hunting usually flee from ple, and this may be desirable for potentially dangerous species such as bears; ever, land managers are having to restrict recreational use of critical habitat to uce wildlife harassment. In fact, critical habitat of wildlife species vulnerable harassment should be the primary target of management aimed at protecting these cies.

In national parks and refuges, many wildlife species are habituated to people accept humans as a harmless element of their natural habitat. Nevertheless, the ssure of recreationists in national parks has increased to the extent that, since 95, a number of studies have been conducted to determine the effects of visitors on life.

Wild animals are an integral component of American wilderness. They are indicators wildness. This bibliography is, in part, a response to the concerns of land managers recreationists who appreciate the value of wildlife and wish to reduce the assing effects of increasing man-wildlife encounters. It is an attempt to determine state-of-the-art--to identify what is already known concerning man-wildlife eractions. Much of the available literature is only peripherally concerned with -wildlife interactions, and the annotations are concerned only with those inter- ons; they are not total abstracts.

Criteria for selection of papers were that they:

1. Describe the interaction of recreationists with some species of wildlife in tural setting; or

2. Present research findings or techniques that could be used to reduce man's ct on wildlife.

Recreation--skiing, backpacking, hiking, photographing, and birdwatching--was idered "backcountry" where it affected wildlife in natural, undeveloped areas her they were wilderness as defined in the 1964 Wilderness Act (PL 88-577) or tly-roaded. However, the emphasis was on lands that were not heavily used by rized vehicles.

---

[1] Wall, G. 1977. Impacts of outdoor recreation on the environment. Council of lanning Librarians, Exchange Bibliography 1363. 19 p.

The effects of hunting and fishing, roads and road construction, logging, and off-road vehicles are not the focus of this paper, but bibliographies, symposia, an literature reviews on these subjects are included in the final section of this bibliography. The references are predominantly North American.

The Wilderness Management Research Work Unit at the Forestry Sciences Laborato in Missoula is presently preparing a bibliography on the impacts of recreation on s and vegetation to complement this bibliography on recreational impacts on wildlife.

EVALUATION OF LITERATURE

The problem with which this bibliography is concerned is unintentional harassm of wild animals. The major source of the problem is the recreationist who innocent produces stressful situations for wildlife. Examples of this type of harassment ar the birdwatcher who pulls down a tree limb to look in a nest or the photographer wh cuts the surrounding vegetation so he can get an unobstructed photograph of a bird Backpackers who camp near a critical waterhole or mineral lick may, without realizi it, inhibit wildlife use of the area. Crosscountry skiers who ski too closely to d or elk, whose movements have been restricted by snow depths and whose strength is exhausted by lack of food, cause stress and unnecessary expenditure of vital energy These and many other innocently produced stressful situations may result in excitem disruption of essential activities, severe exertion, displacement, and possibly death for some animals. Often impacts are not recognized until the damage is irreversible.

Healthy animals with ample food and refuges from sources of disturbance can withstand more harassment than animals that are already experiencing stress as a re of unusual weather condition, malnutrition, giving birth, or living where security areas are not readily accessible. Management efforts are not as critical for these healthy animals.

Human Impacts Literature

The human impacts literature was separated into papers that were mainly concer with harassment or habituation and those that were mainly about a particular animal species, but also included information on human impacts.

HARASSMENT AND HABITUATION

Technology has advanced to the point where we can begin to assess the behavior and physiological effects of human disturbance on big game animals by means of hear rate telemetry, as well as by radio tracking of animal movements. This may prove t a key to understanding the tolerance levels of specific wild populations to differe forms of recreation. The biotelemetry information we have (Ward 1973, 1977; Lieb 1 McArthur and others in press) is significant, as is the work of Moen (1976, 1978) a Geist (1971a) on energy conservation in wintering ungulates. More information on t effects of recreationists on the behavior and physiology of wild animals is needed.

The reality of habituation of wildlife to man is well-documented (Geist 1975b). imals can learn to avoid certain situations (Smith and Geis 1956) and they can bituate to some recreational activities (Geist 1972). A "how to" publication pointing t the benefits as well as pitfalls of habituation would be interesting and useful. wever, application of habituation as a management technique would be unrealistic ere animals are subjected to hunting.

UMAN IMPACTS ON SPECIFIC SPECIES

The reaction of various animal species to human disturbance has only recently been vestigated. Much of the information presented here was extracted from papers that cus on some problem other than human disturbance.

I was unable to locate publications describing backcountry recreation impacts her than fishing) on fish. However, the following examples were brought to my ention:[2]

1. Recreationists harassing spawning fish that are exposed on spawning sites.

2. Salmon reacting positively toward vehicle and stock fords for selection of a wning (redd) site.

3. Salmon redds destroyed by fishermen wading to fish for trout.

The effect of people on nesting birds, especially bald eagles and osprey, is l-documented (Mathisen and others 1977; Garber 1972; and others). Except where ds are habituated, the presence of people is generally a negative impact. Servheen 75), Stalmaster and others (1978), and Shay (1973) have documented human impacts on tering bald eagle populations and made management suggestions.

Presently, the primary effect of people on songbirds and small mammals is indirect ough modification of the structure of the vegetation (Garton 1977; Garton and others 7), rather than direct interaction with the animal. The same is probably true for ects, amphibians, and reptiles. Aggressive birdwatchers, however, can cause gbirds to abandon their territories. Some birds and small mammals are also attracted the food remains of campers (Garton 1977; Garton and others 1977).

Limited information exists on the impact of recreation on hibernating bats and rnity colonies. Structures built at entrances to caves restrict air movements, and temperatures may become too warm for survival of hibernating bats. Disturbances ibernating bats and maternity colonies by recreationists or biologists cause bats ly and use fat reserves critical to winter survival. Unnaturally high mortality lts (Humphrey 1978; Petit 1978).

The only information located on recreational impacts on marine mammals was in lar articles describing harassment of whales by tourists in small boats who to see, photograph, or touch the whales (Payne 1979; Hudnall 1977).

---

[2] Personal Communications. G. Munther, Lolo Nat. For. Fisheries Biologist, Missoula, ., and T. Bjornn, Idaho Coop. Wildlife Unit, Moscow, Idaho.

Cats, wolves, weasels, martens, and other mustelids are poorly represented in
literature on human impacts. Because of their elusiveness, they are difficult to
study and are infrequently seen. Many of these animals require remote wildlands a
undoubtedly man's invasion of the backcountry has affected them. This is an area
needs research. As predators, they are incompatible with agricultural land uses
involving livestock. The literature indicates that wolves and mountain lions requ
protected areas as population reservoirs (Chapman 1977; Peterson 1977; Saile 1977)
Wolves require some protection from trapping and from human intrusion near dens.
require areas with partial protection from hunting, but we know little about man's
as a nonhunting recreationist on any of the cats.

Research on bears has been extensive, with many publications suggesting manag
techniques for both bears and recreationists using bear country. Most of these rel
proper securing of food and disposal of garbage as well as informing the public co
cerning appropriate behavior in bear country. Information on routing trails and
backpackers relative to areas of bear activity is available.

Information is available on elk in relation to highways (Ward 1977), logging
1976), and visitors in national parks (Shultz and others 1978), but we need more
information on the effects of man (disassociated from roads) on wild populations wi
respect to winter range, calving, and distribution on summer range. Human recreati
probably prevents elk from using many important alpine meadows during summer and f

The impacts of snowmobiles, highways, and feral dogs on deer have been researc
Bibliographies covering these subjects are listed in this publication. Deer, like
coyotes, however, are remarkably adaptable as a species and are not in danger of e
tion. Moen's (1976 and 1978) publications on physiological adaptations and Ward's
publication on biotelemetry research on deer are valuable contributions to the har
literature.

Moose are relatively unconcerned about encounters with people (Dennison 1956;
McMillan 1956; DeVos 1958), and, therefore, they are probably not as vulnerable to
harassment as other ungulates. However, because moose are often slower to take fli
than other ungulates, they are more vulnerable to poaching.

Information on caribou is largely a result of research on the potential impact
of the Alaska pipeline. Only the literature dealing with human interactions is
included here. Management recommendations are made in several of these papers.

No papers discussing the effects of recreationists on antelope were found, alt
Ward (1977) has investigated their reactions to highways and fencing.

Publications on mountain goats specifically address problem areas in national
(Bansner 1976; Holroyd 1967; Singer 1978). In these cases, man is sometimes the ta
of harassment from goats. More information on the impact of man as a recreationist
goat populations outside of national parks would be useful.

Among the ungulates, bighorn sheep have received the most attention in the hum
impact literature. DeForge (1962 and 1976), Dunaway (1970 and 1971a, b), and other
believe that human encroachment on bighorn habitat is responsible for the decline i
sheep populations. Research has been conducted to identify the kinds of recreation
that have detrimental effects on sheep (Elder 1977; Hicks 1977). Because sheep are
relatively easily habituated, potential management possibilities are increased (Gei
1975c).

Summarizing the reaction of different animals, even within the same species, to man intruders is very difficult because the responses are so divergent; however, me generalizations relating to management can be made. Critical habitats (waterholes, lt licks, winter ranges, etc.) usually need protection from human intruders. Animals y also need protection during critical times of year. Animals with limited food pplies (ungulates on winter range, bats in hibernacula) are an example. Another ample is the need for protection when young are present. This need is documented in is bibliography for seabirds (Gochfeld 1978; and others), loons (Ream 1976), bald gles (Mathisen and others 1977), osprey (Ames and others 1964; and others), caribou telfox and others 1978), elk (Lieb 1973), and bighorn sheep (Woodward and others 74; and others). Birds and mammals, if frightened, may abandon young and leave them lnerable to predation or excessive heat or cold.

Generally, wild animals are not significantly impacted by low-level, nonaggressive s aring of habitat with man. However, recreationists, because of their numbers and s metimes inappropriate behavior patterns, are causing severe impacts. Some examples a e:

Grizzly bears' existence in Montana depends on their use of low-elevation ranchlands f r part of the year. Bears and ranchers have coexisted for years. Now subdivisions a d ski resorts are being built on some of the ranchlands. These land uses are not c mpatible with bears. People new to the area (and their pets) do not know the rules o bear etiquette. Bears do not know the rules of subdivision etiquette. There are t o many man-bear encounters, and bears are killed.

Sawyers working in the woods frequently report deer and elk feeding in full view wh le they are felling. However, when a massive logging operation is in full swing, th ungulates generally move out. Too many people and too much noise create an intole able situation for these animals.

Loons and eagles traditionally nested on the shores and islands of certain lakes wh ch had only a few residences. As these lakes became ringed by cottages or opened to public water recreation, the birds no longer nested there. The new people (recreationists), because of their numbers and inappropriate behavior, are unacceptable to these birds.

For people and wildlife to coexist, people must behave in a manner acceptable to a mals (and vice versa). Additionally, there is a limit to how many disturbances per unit time (even nonaggressive disturbances) animals will tolerate. This tolerance will vary with each local population, but it is a very important criterion to establish if wild animals are desired in an area.

Harassment Reduction Literature

WILDLIFE MANAGEMENT AND HABITAT MANIPULATION

The distribution of wild animals can be affected by conditioning them positively or negatively to human activities (Geist 1972; Smith and others 1956; Batcheler 1968). Bergerud (1971) has even suggested the possibility of genetic manipulation of caribou to achieve greater tolerance to man's activities or the reverse effect, if that is de red. These techniques will be restricted by the management objectives of specific ar as.

Information on habitat modification specifically designed to control distribution of wildlife is limited. Most of the available information describes the effects of logging, roads, fire, or recreational use on animals. More research on habitat modification specifically designed to attract or divert wildlife would be useful.

For example, Geist and others (1974) suggest the use of fertilizer to attract ungulates to areas of more palatable vegetation. This could be used in habituatin animals to humans or attracting them away from areas of interaction with recreatio Fire, logging, salt, and waterholes have potential for redistributing wildlife. Th field of literature has not been covered in this bibliography. There is considerab information available on the effects of fire and logging on wildlife populations, s of which could be applied in designing research to affect the distribution of wildlife relative to recreation areas.

The use of vegetative screening is a habitat management technique suggested in several papers on species as diverse as bald eagles (Stalmaster 1976; Stalmaster an Newman 1978; Nature Conservancy 1976), elk (Ward and others 1973), and mountain goa (Singer 1978). Screening the visibility of people apparently makes some animals more secure and managers might want to consider this technique. However, animals a sometimes more at ease when they have a clear line of sight of potential danger (Stalmaster 1976; Servheen 1975).

RECREATION MANAGEMENT

Understanding the perceptions and attitudes of recreationist is fundamental to recreation management. This has been accomplished on a national scale by Kellert (1976a, b; 1977a, b). We also need to understand the behavior of recreationists--w they go, where they go, and what they do.

Wildlife education is an important aspect of managing recreational use pattern There are very few wildlife education programs. An assessment of potential methods of sensitizing the public to wildlife problems is needed. Programs at visitor cent the wildlife safari concept (Lime and others 1978), wildlife films for schoolchildr and perhaps a certification program for backcountry users (Wagar 1940) deserve inve gation. This is a fertile field for innovative research.

Popular articles that discuss impacts of recreational activities on wildlife populations are educational. *Ski Trails and Old Timers' Tales* (Watters 1978) has a section on wildlife, warning skiers of the vulnerability of wintering ungulates. O other hand, articles like Curtis' (1977) "Hiking Animal Tráils," which encourage recreationists to follow animal trails, could be detrimental to vulnerable species.

Recent popular articles address the impact of "nonconsumptive users" on wildli Whale-watchers, birdwatchers, and photographers, as well as people who are simply hiking, all affect wildlife. These nonhunters are not actually nonconsumptive. Th also have very significant impacts on wildlife. Articles describing nonconsumptive impacts should help people who are "loving wildlife to death" appraise the situatio especially when they offer guidelines for appropriate behavior and management sugge

An on-the-ground investigation of methods being used by managers to modify vis behavior and use patterns is needed. Innovative techniques similar to those descri Wagar (1975 and 1977) are presently in use in this country. Positively worded signs explanation of impacts; provision of alternative swimming, fishing, and hiking areas timing of recreational use to avoid wildlife-use conflicts; and planning wildlife viewing areas for minimum impact to the animals are all possible solutions. A surve of methods currently in use (including subtle methods) could be followed by research on effectiveness of different methods in various situations. A publication describi various people-management techniques would be useful.

An analysis of the impacts of wilderness management on wildlife (as related to ails, campsites, garbage disposal, improvements, and dispersal of visitors) would enlightening. For instance, the stocking of fish in cirque lakes has an indirect fect on mountain goats because of the increased human use of stocked lakes. Foot-idges allow early spring access to wildlife habitat that might otherwise be disturbed until water levels have lowered. Additional trails on ridges or valley ttoms mean less habitat is available to retiring wildlife species. These are impacts at need consideration in management plans. Unfortunately, the best wildlife habitat also usually the choicest location for campsites, trails, roads, agriculture, cities, c. When running pellet counts on the contour, one soon discovers that very few imals defecate on steep, north-facing slopes with prodigious quantities of downed tmber, or in "dog hair" lodgepole stands. However, at the first pleasant, flat place te ground is invariably liberally sprinkled with pellets.

In conclusion, three approaches to reducing wildlife harassment are evident: (1) Pople management (spatial, temporal, and behavioral); (2) wildlife management, in the snse of modifying behavioral responses to certain recreational activities; and (3) hbitat modification to affect the spatial distribution of wildlife. None of the aproaches offer simple solutions. The behavior of both people and animals is complicted and not easily predicted.

The variation in behavior toward man within single species of animals, sometimes wthin the same location, is demonstrated repeatedly in this bibliography--Mathisen ad others (1977) and Stalmaster and others (1978) for bald eagles; Welles and Welles (961) and Hicks (1977) for bighorn sheep; Altman (1958) for elk; Holroyd (1967) for gts. Some of the behavioral variation is due to variation in the animals' physiolgical state; some is due to an individual animal's past experience; and some is due t the reaction of the rest of the animals in the group. An interesting example is cted in the bighorn sheep section of this bibliography. Light (1971) notes that bhorn ewes with lambs are less tolerant of human approaches than are individual ews and rams. McCann (1956) notes that bighorn ewes and young were tolerant of han presence, but rams took flight at the sight of man. This he considered to be the rult of hunting pressure on rams. Welles and Welles (1961) give many examples of th variation in behavior of individuals within the same band of sheep. Elk in Wyming apparently are much more tolerant of the sight of people than elk in Montana (eb 1976). Although we can say, generally, that moose are not as quick to flee fm man as deer or elk, the variation in individual behavior certainly overlaps; for emple, some moose have a shorter flight distance than some deer.

The behavior of the people interacting with wildlife also ranges from those who tae potshots at animals to unobstrusive observers. For these reasons, it is very dificult to prescribe general management procedures for any species. Management must be specific for each area and conform with the management objectives of the area.

The primary targets of management should be the critical times of the year and ke locations of wildlife species vulnerable to harassment. Time and effort spent in aleviating harassment in other situations is wasted if habitat loss and wildlife motality continue to occur at critical times and places. A perceptive land manager wh has lived in the area a number of years, who has a sound biological background, and wh knows the local climate, weather, topography, and vegetation, as well as the local rereation patterns, is the most qualified person to prescribe a solution fitted to his ara. I hope the papers in this bibliography will provide managers some new insights ino problem solutions. Sometimes an unconventional approach sparks an avalanche of idas, one of which may be a feasible solution.

ORGANIZATION OF BIBLIOGRAPHY AND HOW TO USE INDEX

The major headings of the bibliography are: Human Impacts Literature; Harassment Reduction Literature; and Bibliographies of Closely Related Subjects. All papers are numbered. If the desired information is not included under the headings, check the Keywords Index.

Each publication was put into the category that best described its major emphasi Some papers fit into several categories. In these cases, the number of the paper is cross-referenced under other appropriate headings.

Included in the index is an alphabetical listing of the authors and keywords, wi reference numbers. Common names are used in the keywords index. A taxonomic referen all species occurring in the keywords has been prepared.

The keywords include species (common name), descriptive terms (harassment, dange human disturbance), and place names (Wisconsin, Glacier National Park). Many of the keywords overlap. For example, the words "recreationists," "skiers," "hikers," "phot raphers," etc., all imply human disturbance. When the type of disturbance was not obvious, "human disturbance" was used. "Human impact" was used when the paper inclu effects of people beyond just physical interaction; for example, grazing, subdivisio roads, etc. The word "harassment" implies that the disturbances were excessive.

Each of the indexing systems can be used in looking for sources. For example, when searching for papers on elk management, one can look under (1) "elk" in the major headings; (2) "elk" and "wildlife management" in the keywords and check for matching reference numbers; or (3) authors known to have worked on elk.

Initially, the purpose of this bibliography was to let managers know what inform tion is available. However, it was later realized that annotations on the man-wildli interaction information contained in the papers would be a useful addition. Therefo annotations have been included to the extent possible. Annotations in quotes are fr the authors' abstracts. Although this bibliography will be partially out of date before it is published, because of the growing concern for wildlife it should be useful for references published through 1978. Additional information and publicatio will be graciously received.

Human Impacts Literature

ARASSMENT AND HABITUATION

lso see reference numbers 57, 73, 84, 146, 147, 178, 186, 189, 227)

Blacklock, L.
1977. Encounters in the wild. Natl. Wildl. 15(6):25-29.

Describes how sheep gradually became habituated to author's presence as a photog-pher.
KEYWORDS: Dall sheep, photographers, habituation.

2 Cahalane, V. H.
1940. Some relationships of wildlife to the field of recreation. Utah Juniper 11:8-10.

Points out generally detrimental effect of man on wildlife in recreation areas. ggests that cooperation is essential if wildlife and human use are to be successfully bined on recreational areas.
KEYWORDS: Wildlife, recreation.

3. Carothers, S. W., and S. W. Aitchison.
1976. An ecological survey of the riparian zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs, Arizona. Colorado River Tech. Res. 10, Grand Canyon National Park, Arizona. 251 p. (NTIS Access, No. PB267770AS).

Reports abnormally high and unhealthy populations of rock squirrels and mule deer ulting from feeding by hikers. Lizard populations have been reduced through uction of driftwood which they need for shelter, foraging, etc. Human use causes truction of nests and burrows of ground dwelling vertebrates.
KEYWORDS: Rock squirrels, mule deer, lizards, hikers, Grand Canyon National Park.

4. Chester, J. M.
1976. Human wildlife interactions in the Gallatin Range, Yellowstone National Park, 1973-1974. M.S. thesis. Mont. State Univ., Bozeman. 114 p.

In Gallatin Range of Yellowstone National Park an inverse relationship exists ween intensity of human use and frequency of wildlife observation. Frequency of llife encounters by on-trail and off-trail travelers is described as a function of of year, altitude, noise, and party size. Some management suggestions are given o backcountry recreation.
KEYWORDS: Elk, mule deer, moose, grizzly bear, black bear, bighorn sheep, coyote, hikers, Yellowstone National Park.

5. Clevenger, G. A., and G. W. Workman.
1977. The effects of campgrounds on small mammals in Canyonlands and Arches National Park. Trans. North Am. Wildl. Nat. Resour. Conf. 42:473-484.

Campgrounds have some influence on populations of small mammals inhabiting them. rtunistic feeders such as wood rats, Colorado chipmunks, and deer mice utilized ers' food resulting in higher populations of such species in campgrounds. Ord's aroo rat, desert cottontail, and antelope ground squirrel that did not have higher lations in campgrounds may be more specialized feeders. The amount of escape r near campsites may affect the number of animals using them.
KEYWORDS: Woodrat, Colorado chipmunk, deer mouse, Ord's kangaroo rat, desert cottontail, antelope ground squirrel, campgrounds.

6. Curtis, S.
1977. Hiking animal trails. Backpacker 5(5):44-85.

Tells how to find and follow animal trails on hillsides, in brush or timber, or saddles and passes, and on ridgelines. The author finds that this form of recreati is personally satisfying and allows one to escape crowds.
KEYWORDS: Wildlife, hikers.

7. Fletcher, J. L., and R. G. Busnel, eds.
1978. Effects of noise on wildlife. 320 p. Academic Press, Inc.

Presents data from several disciplines on the effects of noise on behavior and physiology of wildlife and how this information is relative to protecting wildlife and preserving endangered species.
KEYWORDS: Wildlife, noise.

8. Garton, E. O., C. W. Bowen, and T. C. Foin.
1977. The impacts of visitors on small mammal communities of Yosemite Natio Park. *In* Visitor impacts on National Parks: The Yosemite ecological impa study. p. 44-49. T. C. Foin, Jr., ed. Univ. Calif., Davis, Inst. Ecol. 10, 99 p.

Peromyscus maniculatus (deer mice) increased in response to human use of forest areas. *Microtus montanus* (voles) showed no change in density with human use; howeve *Microtus* did withdraw when trampling was heavy enough to eliminate all vegetation. differences in response were attributed to the herbivorous diet and a cyclic nature of population levels of *Microtus*, whereas *Peromyscus* is less subject to population cycles, has a less specialized diet, and may take advantage of food debris left by
KEYWORDS: Deer mice, voles, human impacts, Yosemite National Park.

9. Garton, E. O., B. Hall, and T. C. Foin.
1977. The impact of a campground on the bird community of a lodgepole pine forest. *In* Visitor Impacts on National Parks: The Yosemite ecological impact study. p. 37-43. T. C. Foin, Jr., ed. Univ. Calif., Davis, Inst. Publ. 10, 99 p.

Describes effects of campgrounds on bird communities. Reaction of birds to hum in a campground was highly species-specific and varied even within the species. Bi were affected by modification of the vegetation structure, actual human presence, a the food debris in campgrounds. In this study, Brewer's blackbird, the brown-heade cowbird, and robins were significantly more abundant in campgrounds than the surrounding area and Oregon juncos were significantly less abundant.
KEYWORDS: Brewer's blackbird, brown-headed cowbird, robin, Oregon junco, campgrounds, Yosemite National Park.

10. Geist, V.
1970. A behavioral approach to the management of wild ungulates. *In* Scienti management of animal and plant communities for conservation. p. 413-424. E. Duffer and A. S. Watt, eds. Eleventh Symp. Brit. Ecol. Soc., Blackwell Sci. Publ., Oxford. 652 p.

Gives examples of man and wild ungulates cohabiting towns in Canadian National Parks. States that behavior of wild animals towards humans is largely a consequenc of human behavior toward them. Animals are as wild as man teaches them to be. Cite examples of physical effects of harassment on wild animals. Concludes, "Where visit are common, steps may have to be taken to educate both visitors and the animals."
KEYWORD: Ungulates, harassment, habituation, wildlife management, education, Canadian National Parks.

1. Geist, V.
1971. Is big game harassment harmful? Oilweek 22(17):12-13.

The cost of harassment of big game in the North is considered in terms of energy udgets and physical and hormonal damage. Calculates the "cost" of harassment to big ame in the Canadian arctic and subarctic, in terms of kilocalories/minute above and eyond normal daily expenditures. The amount of forage required by harassed animals ay exceed what is available. Chasing animals in cold weather, through crusted snow, nd during calving may significantly increase mortality. Chronic harassment can result n reduced reproductive rates.

KEYWORDS: Ungulates, winter, harassment.

2. Geist, V.
1972. On the management of large mammals in National Parks. Park News 8(4):7-14, 8(5):16-24.

National Parks should provide for the preservation of natural ecological relationips as well as for the preservation of one viable population of each subspecies of ildlife living within the park boundaries. Park boundaries should be determined iologically, not politically. Research on the biology of large mammals on a speciesecific basis is needed to determine each species' living requirements. In particular, uestions that need to be answered are minimum population size to ensure viable populaions and the impact of human activities on large mammals.

KEYWORDS: Wildlife management, national parks.

. Geist, V.
1975b. Harassment of large mammals and birds. Report to the Berger Commission, MacKenzie Valley Pipeline Inquiry, 62 p.

Excellent definition of harassment, its causes and effects, and animals' defenses ainst harassment. Suggests research direction. Evaluates research submitted by ctic Gas Study Ltd. Examines effects of roads and suggests measures to reduce impact.

KEYWORDS: Birds, wildlife, harassment, aircraft.

. Geist, V.
1975c. Mountain sheep and man in the northern wilds. 248 p. Cornell Univ. Press, Ithaca, N.Y.

Personal experiences of a research biologist studying bighorn sheep in the Canadian ckies. Chapter on author's experiences with habituated sheep and other species of ldlife. Philosophical insights into animal behavior and evolution.

KEYWORDS: Bighorn sheep, habituation, British Columbia.

. Glinski, R.
1976. Birdwatching etiquette: the need for a developing philosophy. Am. Birds 30:655-657.

Points out types of disturbance caused by birdwatchers and the lack of regulation interactions of man with nongame species of wildlife. Lists five rules of etiquette a foundation for birdwatchers to build on:

1. Avoid use of tape recorded territorial calls of rare birds during their eeding season.
2. Do not cause disturbance at nests.
3. Do not harass rare birds.
4. Respect property and wishes of private landowners.
5. Do not patronize large groups of birdwatchers lacking responsible guides.

KEYWORDS: Birds, birdwatchers.

16. Hammond, J. L.
1974. The role of wilderness areas in wildlife management. Pac. Wilderness J. 1(6):10-11.

Points out that wildlife is an integral component of wilderness, and that many species need the protection that wilderness management can provide. Some wildlife species apparently cannot live in close proximity to man.

KEYWORDS: Wildlife, wilderness, harassment.

17. Hudnall, J.
1977. In the company of great whales. Audubon 79(3):62-73.

Describes harassment of whales in California where fleets of boats follow migr gray whales, and in Hawaii where whale watchers in powerboats "dive-bomb" surface wh frighten cow and calf humpbacks from traditional nursery refuges, and interrupt cou whales. In some areas hydrofoils pass through whale mating and calving areas sever times a day. In addition to disturbance and possibility of collision, hydrofoils in the singing of humpbacks. Author proposes rerouting hydrofoils, regulating numbers whale-watching boats, and a national park or wildlife refuge to protect Hawaiian hu backs.

KEYWORDS: Humpback whale, gray whale, harassment, recreation management, Hawai California.

18. Johnson, R. R.
1977. Synthesis and management implications of the Colorado River research program. Grand Canyon National Park Colorado River Series, Contribution 47, 75 p.

Contains short section on impact of recreationists on vertebrates in the Grand Canyon. Data cited are from Carothers and Aitchison, 1976.

KEYWORDS: Rock squirrels, mule deer, lizards, recreation, Grand Canyon Nationa Park.

19. Kregosky, B.
1972. 1971 Great Divide Trail impact study. Can. Wildl. Serv. (unpubl. rep. 215 p. Edmonton, Alberta.

Includes section on the potential effects of the development of the Great Divid Trail on the local fauna from ground squirrels through ungulates and bears. Express concern about disturbance heavy trail use may cause to retiring species of animals. The result may be further reduction of habitat for species whose existence is alread threatened by man. Ungulates may abandon migration routes in areas where trail use heavy. Bears may be attracted by refuse. Coyotes and some small mammals may increa deriving sustenance from campers.

KEYWORDS: Wildlife, trail impacts.

20. Leopold, A. S. (Chairman)
1963-1968. Reports of the Special Advisory Board on Wildlife Management. Tr North Am. Wildl. Nat. Resour. Conf. 28, 29, 33.

Examples of effect of man on wildlife in refuges. Suggests management that wil restore wildlife to wild condition. Wildlife enhancement should take precedence over recreation in refuges.

KEYWORDS: Wildlife management, refuges.

21. Lieb, J. W.
1978. Biotelemetric monitoring of heart rate and activity in elk. USDA For. Serv., Intermt. For. and Range Exp. Stn., Final Progr. Rep., Res. Work Unit FS-INT-1705, 36 p. Ogden, Utah.

Heart rate activity biotelemetry systems were installed in captive elk. The systems did not perform as effectively as had been expected; however, meaningful data were collected. Heart rate and signal strength traces could be reliably interpreted as specific elk activities. Seasonal mean heart rates were dependent on ambient temperature, increasing from a winter low to a summer high. This system will be very valuable to the wildlife manager/biologist for determining the effects of disturbance, habitat change, or management programs.
KEYWORDS: Elk, heart rate telemetry, Montana.

22. Lynch, J. F., and N. K. Johnson.
1974. Turnover and equilibria in insular avi faunas, with reference to the California Channel Islands. Condor 76:370-384.

Many island extinctions and colonizations are related to human influences. These nfluences include the impact of habitat modification, introduction of nonnative species, which through competition or predation eliminate native species, and the impacts of pesticides and shooting.
KEYWORDS: Birds, island populations, California Channel Islands.

3. Ream, C. H.
1979. Human-wildlife conflicts in backcountry: possible solutions. p. 153-163. *In* Recreational Impacts on Wildlands. Proc. R. Ihner, D. R. Potter, and J. K. Agee, eds. USDA For. Serv., Nat. Park. Serv., Pac. Northwest Region.

Biological, sociological, managerial, and popular literature was reviewed to dentify the extent of human impacts on wildlife in the backcountry, and possible olutions. A major problem was recreationists who innocently produced stressful ituations for wildlife. Suggested solutions included: people management (spatial, emporal, and behavioral); wildlife management, in the sense of modifying wildlife ehavior responses to certain recreational activities; and habitat modification to ffect the spatial distribution of wildlife.
KEYWORDS: Wildlife, human disturbance, recreation management, wildlife management, habitat modification.

4. Rymon, L. M.
1969. A critical analysis of wildlife conservation in Oregon. Ph.D. dissertation. Oreg. State Univ., Eugene. 441 p.

Study of Oregon's wildlife resources from before white settlement to present, ncluding projections, based on present trends, up to the year 2010. Oregon's wildlife s decreasing due to competition with man for living space and resources. It appears hat increasing human population may eventually eliminate many species of wildlife.
KEYWORDS: Wildlife, human impacts, Oregon.

25. Scheffer, V. B.
1974. A voice for wildlife. 245 p. Charles Scribner's Sons, New York.

Briefly acknowledges the impact of bird and beast watching on wildlife especiall during breeding seasons. Suggests the possibility of a "Wildlife Education Associati to develop wildlife education programs for all educational levels. This book is main concerned with impact of hunting, trapping, and other consumptive activities on wildl populations.
KEYWORDS: Wildlife, human impacts, education.

26. Schieffelin, J. B.
1973. The political aspects of wildlife management. *In* Wildlife and the environment: Proceedings of the Governor's Conference March 1973, Denver, Colo. p. 78-81. E. Decker and G. A. Swanson, eds. Environ. Resourc. Cent., Colorado State Univ., Infor. Series 7, 119 p.

Recreational areas are eliminating wildlife habitat. The more people in an area on foot, skis, and snowmobiles, the more the wildlife is pushed back. Recommends controlled development.
KEYWORDS: Wildlife, recreation.

27. Sheridan, D.
1978. Dirt motorbikes and dune buggies threaten deserts. Smithsonian 9(5):65-75.

People driving ORV's are destroying desert habitats. In moderately used ORV area plant life declined 50 percent; terrestrial animal life, 60 percent. In areas where ORV'ers congregate, plant life is reduced 90 percent and animal life 75 percent.
KEYWORDS: Desert animals, ORV's.

28. Stebbins, R. C.
1974. Off-road vehicles and fragile desert. Am. Biol. Teach. 36(4):203-208, 220 and 36(5):294-304.

People driving ORV's are maiming and killing ground-nesting birds, lizards, and snakes. ORV's cause collapse of burrows, soil compaction, depletion of forage, and vandalism (desert tortoise) in previously inaccessible areas.
KEYWORDS: Desert animals, ORV's.

29. Steinhart, P.
1978. Off we go, into the wild green yonder. Natl. Wildl. 16(4):16-19.

Describes the effects of aircraft harassment on elephant seal rookeries, condors, wolves, bison, waterfowl, etc. Describes behavioral changes in animals subjected to this impact. Suggests mandatory rather than advisory altitude of 2,000 feet over the terrain of parks, wilderness, and wildlife refuges.
KEYWORDS: Wildlife, aircraft, harassment.

30. Telfer, E. S.
1978. Cervid distribution, browse and snow cover in Alberta. J. Wildl. Manage. 42(2):352-361.

Studies of winter distribution of moose, elk, and mule deer. Moose utilization was positively related to browse. Deer and elk utilization was not strongly related to browse availability, but may be related to traditional winter ranges and human disturbance. Recommends maintaining the integrity of traditional winter range for deer and elk. Moose populations can be managed by manipulating browse supply.
KEYWORDS: Moose, elk, mule deer, winter, human disturbance, wildlife management, Alberta.

31. Tracy, D. M.
1977. Reaction of wildlife to human activity along the Mount McKinley National Park road. M.S. thesis. Univ. Alaska, Fairbanks. 260 p.

Some bears and foxes, and possibly, large bands of caribou avoided the McKinley ark road. Some road crossings by migrating sheep were thwarted by disturbances. isturbances caused caribou within 200 m of the road to decrease feeding and increase ovements. For ungulates, females with young were most easily disturbed. Individual nimals appeared to be habituated to human activity. Most species exhibited more esponse to loud noises and people out of vehicles. Good bibliography on disturbance nd flight distance. Peripheral information included on park regulations protecting ildlife. Includes management suggestions.
KEYWORDS: Caribou, moose, dall sheep, brown bear, wildlife, wildlife management, human disturbance, bibliography, highway, McKinley National Park.

2. Ward, A. L.
1977. The effects of highway operation practices and facilities on elk, mule deer and pronghorn antelope. Project No. 942-41-42-13-0088-33F2-6-2580. 53 p. Annu. Rep. Fed. Highway Admin., Office of Research and Development Washington, D.C.

A study to determine the impact of Interstate 80 on elk, deer, and antelope winter ange. Includes information on heart-rate-telemetered mule deer and elk. Heart rate esponses to human activities, dogs, vehicles, cattle, other wildlife, and the sound of hooting are reported. Out-of-vehicle activities caused more change in heart rate than oving vehicles. Heart rate telemetry can be effectively used to measure the effect of an on wildlife.
KEYWORDS: Elk, mule deer, antelope, heart rate telemetry, highways, Wyoming.

3. Ward, A. L., J. J. Cupal, G. A. Goodwin, and H. D. Morris.
1976. Effects of highway construction and use on big game populations. Fed. Highway Admin. Off. of Res. Develop. Rep. No. FHWA-RD-76-174, 92 p. Washington, D.C.

Antelope were not disturbed by moving traffic. Fences kept antelope off highway, ut deer went over fences and did not use the provided underpasses. Suggests the need r deer-proof fences. Elk were more affected by moving traffic than deer and telope. Potential usefulness of heart rate telemetry for assessing human impacts on ldlife is recognized. The authors state, "Land managers and wildlife biologists st know the effects of human behavior on wildlife species to make proper plans for e use of land without losing the wildlife resource."
KEYWORDS: Antelope, mule deer, elk, highway, heart rate telemetry, wildlife management.

. Waterman, G., and L. Waterman.
1977. Dogs on the trail. Backpacker 5(4):29-32.

Dogs harass wildlife and other backpackers. Dog owners must keep dogs under ntrol and see that their behavior is acceptable to other campers.
KEYWORDS: Wildlife, backpackers, dogs.

5. Watters, R.
1978. Ski trails and old timers' tales in Idaho and Montana. 272 p. Solstice Press, Moscow, Idaho.

This guide to crosscountry skiing has a section on wildlife which warns skiers out the threat they pose to wildlife. If wild animals are forced to run they expend al energy reserves. Suggests dogs be left at home when skiing in big game wintering eas.
KEYWORDS: Wildlife, winter, skiers, Montana, Idaho.

36. Weeden, R.
1976. Nonconsumptive users: a myth. Alaska Conserv. Rev. 27(9):3,15.

Dismisses the notion of consumptive vs. nonconsumptive uses of wildlife with examples of detrimental effects of "nonconsumptive users" on wildlife. Concludes th is no such thing as a nonconsumptive user; there are only consumers who care about wildlife and those who do not.
KEYWORDS: Wildlife, human disturbance.

37. Whitcomb, R. F., J. F. Lynch, P. A. Opler, and C. S. Robbins.
1976. Island biogeography and conservation: strategy and limitations. Scien 193:1030-1032.

Discusses the need for establishing faunal reserves that are large enough to prevent faunal extinction. Human impact is one problem that may be reduced by setti aside large continuous natural areas.
KEYWORDS: Forest birds, human impacts, island populations.

38. Wilkes, B.
1977. The myth of the non-consumptive user. Can. Field-Nat. 91(4):343-349.

Rejects the concept that outdoor recreational activities, other than hunting an fishing, are nonconsumptive. Points out the impact of naturalists, photographers, e on the vegetation and wildlife. Proposes licensing back-country users and regulatin numbers through a permit system. Suggest a skills test associated with licensing because of the damage caused by uninformed, unskilled people.
KEYWORDS: Wildlife, photographers, back-country certification, recreation management.

39. Williams, R.
1978. Energy crisis. Idaho Wildlife 1(6):33.

This editorial points out the stresses confronting wildlife during the winter: cold, snow, limited food, energy drains from rut and gestation. Suggests that photographers, skiers, and snowmobilers avoid unnecessary harassment of wildlife and that dogs and cats be kept under control year around, especially during the winter.
KEYWORDS: Wildlife, harassment, winter, photographers, skiers, dogs.

40. Wright, G. M., J. S. Dixon, and B. H. Thompson.
1933. Fauna of the National Parks of the U.S. A preliminary survey of fauna relations in national parks. Fauna Series No. 1. U.S. Govt. Print. Off., 157 p. Washington, D.C.

Recognized the importance of wildlife in American heritage and the dependence o these animals on remote wild country provided by national parks. Reports on a general investigation of wildlife in national parks with emphasis on the effects of r Many individual accounts of the effects of park visitors on different species of bir and mammals. Emphasis on humans making adjustments rather than the animals.
KEYWORDS: Wildlife, national parks.

41. Wright, G. M., and B. H. Thompson.
1934. Fauna of the National Parks of the U.S. Fauna Series No. 2. U.S. Govt Print. Off., 142 p. Washington, D.C.

Emphasizes the joint occupation of wildlife and man in national parks in primiti or wild settings. Includes examples of wildlife (osprey, cranes, geese, pelican, be and moose) in wilderness-type situations living in close contact with man, encourage by the exercise of restraint on man's part.
KEYWORDS: Wildlife, habituation, national parks.

HUMAN IMPACTS ON SPECIFIC SPECIES

General Wildlife

(Also see reference numbers 212, 224-231; also see wildlife in keywords)

2. Hornocker, M.
1978. Interactions between threatened and endangered species and wilderness. Trans. North Am. Wildl. and Nat. Resour. Conf. 43:344-350.

Wilderness is a natural laboratory that can provide the baseline data against hich man's impact on wildlife, especially endangered species can be measured.
KEYWORDS: Endangered species, human impact, wilderness.

3. Dixon, J. S.
1938. Birds and mammals of Mount McKinley National Park. Fauna of the National Parks of the U. S. Fauna Series No. 3. U.S. Govt. Print. Off., 236 p. Washington, D.C.

Numerous accounts of reactions of various wildlife species to man recorded during he field work for this publication.
KEYWORDS: Wildlife, Mount McKinley National Park.

nsects

4. Mahoney, C. L.
1976. Soil insects as indicators of use patterns in recreation areas. J. For. 74(1):35-37.

Population densities of *Collembola* may be useful indicators of intensity of use n campgrounds. Reduction in numbers of individuals and species was related to more ntensive campground use.
KEYWORDS: Soil insects, campgrounds, Colorado.

eptiles

Also see reference numbers 3, 18, 27, 28, 226, 232, and the keyword desert animals)

5. Bury, R. B., and B. W. Marlow.
1973. The desert tortoise. Will it survive? Natl. Parks Conserv. Mag. 47(6):9-12.

Discusses the severity of the direct impact of modern man on desert tortoise opulations as well as man's impact on desert tortoise habitat.
KEYWORDS: Desert tortoise, human impact.

irds

Also see reference numbers 9, 13, 15, 22, 27, 28, 37, 185, 187, 216, and the keyword esert animals)

6. McIntyre, J. M. W.
1975. Biology and behavior of the common loon (*Gavia immer*) with reference to its adaptability in a man-altered environment. Ph.D. dissertation. Univ. Minn., Minneapolis. 243 p.

Discusses the impact of increased recreational use of lakes on loons. The annual iology of loons was studied to assess their ability to adapt.
KEYWORDS: Common loon, water recreation, Minnesota.

47. McIntyre, J. M. W.
1977. Spring calls the loons. Minn. Volunteer Mar.-Apr.: 22-26.

Recreationists too close to loon nests cause adult birds to sneak off nests an leave eggs vulnerable to predators. Newly hatched chicks are also vulnerable to predation when parent birds are frightened away. Suggests recreationists move away from obviously agitated loons.

KEYWORDS: Common loon, water recreation.

48. Ream, C. H.
1976. Loon productivity, human disturbance, and pesticide residues in northe Minnesota. Wilson Bull. 88(3):427-432.

Increasing use of loon nesting islands by canoeists for camping appears to be primary cause of decrease in loon productivity in the Boundary Waters Canoe Area. Pesticide residues are a potential danger on some lakes.

KEYWORDS: Common loon, water recreation, pesticides, Boundary Waters Canoe Are Minnesota.

49. Thompson, B. H.
1936. The problem of vanishing species-the trumpeter swan. North Am. Wildl. Conf. 1:639-641.

Discusses the causes of mortality of the trumpeter swan. Cites instance where fishermen disturbed nesting pair at an isolated lake so that they failed to hatch cygnets.

KEYWORDS: Trumpeter swan, human disturbance, Montana, Wyoming.

50. Kuchel, C. R.
1977. Some aspects of the behavior and ecology of harlequin ducks breeding i Glacier National Park. M.S. thesis. Univ. Mont., Missoula 147 p.

Harlequin ducks require pristine stream ecosystems and relative seclusion from human interference for successful breeding. Alteration of stream courses, contamina by human sewage, siltation from construction, and clearing stream channels of fallen trees are discouraged.

KEYWORDS: Harlequin ducks, wildlife management, Glacier National Park.

51. Ames, P. L., and G. S. Mersereau.
1964. Some factors in the decline of the osprey in Connecticut. Auk 81:173-

Reports effects of human disturbance on osprey nesting. Nests were deserted because picnickers repeatedly kept birds from incubating. Eggs were broken by osprey flushing from ground nests when frightened by speeding motorboats. Nevertheless, hur activity was not considered a major factor in hatching failure. Reproductive success remotely located nests was lower than from nests more exposed to human activity.

KEYWORDS: Osprey, water recreation, Connecticut.

52. Dunstan, T. C.
1968. Breeding success of osprey in Minnesota from 1963 to 1968. Loon 40:10 112.

In Minnesota, perhaps due to increased travel by watercraft, ospreys seem to be building nest farther from lake and river shores. Osprey eggs may be chilled or ove heated when people frighten incubating adults from the nests.

KEYWORDS: Osprey, water recreation, Minnesota.

3. Dunstan, T. C.
1973. The biology of ospreys in Minnesota. Loon 45:108-113.

Reports osprey nest failure due to human disturbance. Notes a trend for change n nest location away from lakes used by osprey for fishing. Suggests increase of ecreational use of these areas may be responsible.
KEYWORDS: Osprey, water recreation, Minnesota.

4. Elrod, M. J.
1897. The American osprey in the Yellowstone National Park. Osprey 1:143.

Ospreys nesting in the Grand Canyon of Yellowstone were not noticeably disturbed y tourists on the rim.
KEYWORDS: Osprey, Yellowstone National Park.

5. French, J. M.
1972. Distribution, abundance, and breeding status of ospreys in northwestern California. M.S. thesis Humboldt State Univ., Arcata, Calif. 58 p.

Found very low level of significance in the differences of osprey nest failure ssociated with four levels of magnitude of human disturbance. Some ospreys abandoned ests possibly due to disturbance while others successfully raised young in spite of isturbance. Section on management implications.
KEYWORDS: Osprey, human disturbance, wildlife management, California.

. Garber, D. P.
1972. Osprey nesting ecology in Lassen and Plumas Counties, California. M.S. thesis. Humboldt State Univ., Arcata, Calif. 59 p.

Section on human disturbance of nesting birds. Thirty-three percent of egg loss study area attributed to human disturbance. Human disturbance may also cause emature flight of young osprey resulting in injury and predation. Major causes of productive failure were the destruction of nests by winds and the breakage of eggs nests. Eggshell thinning resulting from metabolites of DDT was implicated.
KEYWORDS: Osprey, human disturbance, pesticides, California.

. MacCarter, D. L.
1972. Reproductive performance and population trends of ospreys at Flathead Lake, Montana. M.S. thesis. Humboldt State Univ., Arcata, Calif. 80 p.

Effects of human disturbance on osprey populations in Montana study area minimal. prey on Flathead Lake are almost through incubation by the time summer visitors rive in mid-June. Removal of snags, which have potential as nesting sites, may fect breeding population. The most important factor in lowered reproductive performce was thought to be DDT contamination of the eggs. Gives evidence that ospreys can apt to nesting in populated areas if people are interested in protecting the birds.
KEYWORDS: Osprey, human impacts, habituation, pesticides, Montana.

. Reese, J. G.
1970. Reproduction in a Chesapeake Bay osprey population. Auk 87:747-759.

Major cause of nest loss in study area was due to the efforts of the U.S. Coast ard to keep navigation aids (which were being used as nesting platforms by osprey) bstructed.
KEYWORDS: Osprey, human impacts, Chesapeake Bay.

59. Reese, J. G.
1972. Osprey nesting success along the Choptank River, Maryland. Chesapeake
Sci. 13:233-235.

Birds nesting on offshore channel markers and duck blinds are disturbed by increasing numbers of visitors in boats. Considers that increasing human disturbanc has an adverse effect on osprey reproduction. Nests on channel markers are destroye by the U.S. Coast Guard.

KEYWORDS: Osprey, water recreation, Maryland.

60. Rhodes, L. I.
1972. Success of osprey nest structures at Martin National Wildlife Refuge.
Wildl. Manage. 36:1296-1299.

Speculates that lack of human disturbance and relative lack of chemical polluta may be the reasons for the success of platform-nesting ospreys on Martin refuge in Chesapeake Bay.

KEYWORDS: Osprey, Chesapeake Bay.

61. Schmidt, F. C.
1966. The status of the osprey in Cape May County, New Jersey between 1939 a
1963. Chesapeake Sci. 7:220-223.

Suggested reasons for the long term nature of osprey decline are: increasing frequency of human disturbance and nest destruction, diminishing food supply, and increasing concentrations of industrial contaminants in the food chain.

KEYWORDS: Osprey, human impacts, New Jersey.

62. Schroeder, G. J.
1972. Results of a two year investigation of the ospreys of northern Idaho.
M.S. thesis. Univ. Idaho, Moscow. 63 p.

Effects of human disturbance on osprey in Idaho study area are considered to be minimal; however, examples of shooting ospreys and nesting disturbance by humans are cited.

KEYWORDS: Osprey, human disturbance, Idaho.

63. Grier, J. W.
1969. Bald eagle behavior and productivity responses to climbing to nests.
Wildl. Manage. 33:961-966.

Single climbs by researchers into bald eagle nests containing 2- to 11-week-old young had no measurable effect on subsequent productivity.

KEYWORDS: Bald eagle, human disturbance.

64. Juenemann, B. G.
1973. Habitat evaluations of selected bald eagle nest sites on the Chippewa
National Forest. M.S. thesis. Univ. Minn., St. Paul. 170 p.

Describes effects of human disturbance on bald eagle nesting activity.

KEYWORDS: Bald eagle, human disturbance.

55. Mathisen, J. E.
1968. Effects of human disturbance on nesting bald eagles. J. Wildl. Manage. 32(1):1-6.

Human disturbance on the Chippewa National Forest, Minnesota, was not considered o cause nesting failure of eagles; however, disturbance earlier in incubation might ave an effect.

KEYWORDS: Bald eagles, human disturbance, Minnesota.

6. Mathisen, J. E., D. J. Sorenson, L. D. Frenzel, and T. C. Dunstan.
1977. Management strategy for bald eagles. Trans. North Am. Wildl. and Natl. Resour. Conf. 42:86-92.

Bald eagle nest protection on the Chippewa National Forest, Minnesota, proved to be nadequate prior to 1974. Implementation of eagle nest protection included requirement f detailed management plan for forest areas in which nests occur, improved buffer one specifications, and taking into account the known responses of particular eagle airs to various types of human intrusion. The security of nesting birds was improved y closing some areas, seasonal restrictions, and rerouting of travelways.

KEYWORDS: Bald eagles, wildlife management, Minnesota.

7. Murphy, J. R.
1960. Ecology of the bald eagle in Yellowstone National Park: Progress report summer of 1960. Unpubl. rep., Yellowstone National Park, Wyo. 6 p.

One factor in nest site selection by eagles in Yellowstone was freedom from disturbnce. Cites specific examples for eagles nesting in Yellowstone.

KEYWORDS: Bald eagle, human disturbance, Yellowstone National Park.

8. Nature Conservancy.
1976. Skagit eagles: a management program for the Skagit River Bald Eagle Natural Area. The Nature Conservancy, Portland, Oreg. 52 p.

A population of 100-200 bald eagles winter on the upper Skagit River. Wintering agles and the salmon on which they feed have shown a long term decline. Decline of igles was attributed to habitat elimination and loss of solitude at nesting areas due increased use of these areas by man, pesticide contamination, shooting, and poisoning eagles. Critical habitat along a 7-mile stretch of the Skagit River has been quired for public trust ownership and designated as the Skagit River Bald Eagle tural Area. Management recommendations for this area are to enhance eagle viewing hile still providing maximum possible protection of the eagles. From late April to rly October, when eagles are not present, many forms of outdoor recreation are permitted. ring the winter, general outdoor recreation is not permitted. Bank fishing is not lowed.

KEYWORDS: Bald eagle, winter, human impact, wildlife management.

. Servheen, C. W.
1975. Ecology of the wintering bald eagles on the Skagit River, Washington. M.S. thesis. Univ. Wash., Seattle. 96 p.

The decline in bald eagle populations is attributed to habitat destruction, shooting d poisoning, loss of solitude at nesting areas, and pesticide contamination. Wintering gles in the study area preferred areas where food was abundant and there was the ast amount of human disturbance. The author feels that with proper regulation of land e, fishermen, recreationists, and birdwatchers can co-exist with eagles. Management ggestions include maintenance of natural spawning salmon populations, and restriction boat landing and development along specific sections of the river.

KEYWORDS: Bald eagle, winter, human impact, recreation management, wildlife management, Washington.

70. Shay, D. S.
1973. A management-oriented study of bald eagle concentrations in Glacier National Park. M.S. thesis. Univ. Mont., Missoula. 78 p.

Greatest danger to bald eagles in Glacier National Park is the disruption caus by eagle-watchers. The author recommends: Protecting eagle roosting and nesting ar from human disturbance, maintaining a policy of no salmon snagging or boating on McDonald Creek from October 15 to December 15 (except for eagle census), prohibitin snowmobile use on trail near McDonald Creek, and a better eagle-viewing and educati program.

KEYWORDS: Bald eagle, winter, birdwatchers, recreation management, Glacier Na Park.

71. Sprunt, A.
1969. Population trends of the bald eagle in North America. *In* Peregrine f populations: their biology and decline. p. 347-351. J. J. Hickey, ed. Wis. Press, Madison. 596 p.

Decline in bald eagle populations attributed to human disturbance, habitat los shooting, and other undetermined factors.

KEYWORDS: Bald eagle, human impact.

72. Stalmaster, M. V.
1976. Winter ecology and effects of human activity on bald eagles in the Noo River valley, Washington. M.S. thesis. West. Wash. Univ., Bellingham.

Evaluates the effects of human presence and activities on the behavior of wint eagles. The most disruptive human activity is drift and motor boating, second is re tional viewing of eagles, and third is shore and river fishing. Concludes that Nool River eagle population is threatened by human interference. Management recommendat include protection of eagle population and salmon spawning grounds, use of vegetati buffer zones, prohibition of boating along prime feeding areas, restriction of logg practices along wintering grounds, construction of interpretive displays for visito information, and a 300-meter activity-restriction zone.

KEYWORDS: Bald eagle, winter, human disturbance, recreation management, wildl management, Washington.

73. Stalmaster, M. V., and J. R. Newman.
1978. Behavioral responses of wintering bald eagles to human activity. J. W Manage. 42(3):506-513.

The authors found that wintering bald eagles moved to areas of lesser human act Older birds were more sensitive to disturbance than younger ones. Eagles reacted th most to disturbances which occurred in the water and on gravel bars, and less to lar disturbances, especially when vegetation partially obscured visibility. Eagles seen habituate to normal activities. Recommends reduced human interference, activity res tion zones, and vegetation buffer zones for bald eagle wintering grounds.

KEYWORDS: Bald eagles, winter, human disturbance, habituation, recreation mana ment, Washington.

74. Swenson, J. E.
1975. Ecology of the bald eagle and osprey in Yellowstone National Park. M. thesis. Mont. State Univ., Bozeman. 146 p.

Found definite effects of human activities on osprey reproduction. Bald eagles are quite tolerant of human presence during late incubation and after hatching but disturbance during initiation of nesting could be disruptive. Presence of fishermen had no influence on osprey foraging. Management suggestions made.

KEYWORDS: Bald eagle, osprey, wildlife management, human disturbance, Yellowst National Park.

75. Windsor, J.
1975. The response of peregrine falcons *(Falco peregrinus)* to aircraft and human disturbance. Can. Wildl. Serv., Edmonton. 87 p. [Draft prepared for the Environmental Social Program, Northern Pipeline]

Discusses effects of hikers and aircraft on peregrine falcons. Peregrine can islodge eggs and young from nests when suddenly flushed by a person, aircraft or predaor. Management recommendations include: aircraft should maintain altitudes of 750 m bove sea level and hiking trails should not be closer than 1 500 m from the aerie, ith a minimum of 800 m if trail is not visible from the nest.
KEYWORDS: Peregrine falcon, aircraft, trail impact, wildlife management.

6. Sowl, L. W., and J. C. Bartonek.
1974. Seabirds-Alaska's most neglected resource. Trans. North Am. Wildl. Nat. Resour. Conf. 39:117-126.

At the approach of man, cliff nesting seabirds flush, and may cause eggs and young o fall and be destroyed.
KEYWORDS: Seabirds, human disturbance, Alaska.

7. Hunt, G. L., Jr.
1972. Influence of food distribution and human disturbance on the reproductive success of herring gulls. Ecology 53:1051-1061.

Hatching success of Maine herring gull colonies that were visited by picnickers as significantly lower than those that were not. Mortality was attributed to mbryonic overheating while parents were off eggs as a result of human disturbance.
KEYWORDS: Herring gull, human disturbance, Maine.

8. Gochfeld, M.
1978. Terns in traffic. Nat. Hist. 87(6):54-61.

Reports history of tern nesting colonies in New York as affected by man. Describes teractions of common terns and people on New York beaches. Terns can nest successfully ar intensively used beaches if they are not harassed, stomped on, or run over by cars.
KEYWORDS: Common tern, harassment, New York.

Bats

9. Humprey, S. R.
1978. Status, winter habitat and management of the endangered Indiana bat, *Myotis sodalis*. Fla. Sci. 41(2):65-76.

Populations of the Indiana bat are declining, due in part to disturbance by ologists and caving enthusiasts. Winter disturbance of bats causes them to utilize t reserves needed to survive the winter. Structures built at cave entrances may strict air movements making the temperature of bat roosts too warm for survival of bernating bats because of resulting increased metabolism of fat reserves. Recommends placing structures closing entrances to cave with strong gates which would restrict sitor access, yet allow free air circulation and access by bats. Also recommends t more than one winter visit to each hiberculum.
KEYWORDS: Indiana bat, winter, human disturbance, wildlife management.

80. Petit, M. G.
1978. The imperiled bats of Eagle Creek Cave. Nat. Hist. 87(3):50-55.

A maternity colony of Mexican free-tailed bats is decreasing about 10 percent e year at Eagle Creek Cave. Pesticides are considered to be the primary cause of this decline. People shooting into the cave cause additional mortality due to stress. T save these bats the maternity colonies need protection and the use of fat soluble pesticides in the foraging area needs to be restricted.
KEYWORDS: Mexican free-tailed bat, pesticides, human disturbance, Arizona.

Rodents

(See reference numbers 3, 5, 8, 18, 19, 27, 28)

Cetaceans (Whales)

(Also see reference number 17)

81. Payne, R.
1979. Humpbacks: their mysterious songs. Nat. Geogr. 155(1):18-25.

In Hawaii, whales are being harassed on their breeding grounds by well-meaning tourists in small boats who want to see and photograph the whales. An official orga zation has been formed to educate the public and thus prevent harassment.
KEYWORDS: Humpback whales, harassment, education, Hawaii.

Carnivores

Wolves, Coyotes, Foxes

(Also see reference numbers 4, 19, 31, 154)

82. Chapman, R. C.
1977. The effects of human disturbance on wolves *(Canis lupus L.)* M.S. thes Univ. Alaska, Fairbanks. 209 p.

Wolves responded to humans near pups by barking or howling, leaving the area, o moving the pups. Low intensity disturbance does not seem to cause significant pup mortality. Recommends closing areas of 2.4 km radius around homesites to disturbanc from 4 or 5 weeks before whelping until wolves leave the area. Contains appendix o more than 100 published and unpublished accounts of wolf reactions to disturbance. Source for additional accounts of wolf/man interactions.
KEYWORDS: Wolves, human disturbance, wildlife management, bibliography.

83. Grace, E. S.
1976. Interactions between men and wolves at an arctic outpost on Ellesmere Island. Can. Field-Nat. 90(2):149-156.

Reports records of wolf-man interactions from early years at the arctic weathe station and compares them with present wolf behavior. Wolves generally avoided huma and domestic dogs. Most wolves were seen at or near settlement dump. Due to the negative effects of dumps on wolf behavior and ecology, the author suggests garbage be incinerated or fenced off.
KEYWORDS: Wolves, wildlife management, Ellesmere Island, Canada.

84. Mech, L. D.
1966. The wolves of Isle Royale. Fauna of the National Parks of the U.S. Fauna Series No. 7. U.S. Govt. Print. Off., Washington, D.C. 210 p.

Gives occasional insights into the responses of wolves to the researcher on the ground, and to the aircraft used for observations. The researcher was not threatened by wolves, even when he examined recent kills. The wolves became habituated to the airplane used for observations and usually did not run even when repeatedly buzzed as low as 40 feet.
KEYWORDS: Wolves, aircraft, Isle Royale National Park.

85. Murie, A.
1944. The wolves of Mount McKinley. Fauna of the National Parks of the U.S. Fauna Series No. 5. U.S. Govt. Print. Off., Washington, D.C. 238 p.

Occasional insights into the response of Mount McKinley wildlife to the author. Also includes information on behavior of captive wolves.
KEYWORDS: Wolves, dall sheep, Mount McKinley National Park.

86. Peterson, R. O.
1977. Management implication of wolf-moose research, Isle Royale National Park, Mich. Rep. to the Natl. Park Serv. 14 p.

Wolves of Isle Royale tend to avoid contact with humans. Wolf use of park trails declines after visitors arrive in the spring. Selection of den and rendezvous sites indicates pronounced avoidance of humans. Management suggestions include limiting visitation, enlarging existing backcountry campsites rather than establishing new campgrounds, no further trail development, and discouragement of winter visitor use.
KEYWORDS: Wolves, human disturbance, winter, recreation management, Isle Royale National Park.

Bears

Also see reference numbers 4, 19, 31, 154, 195, 210)

7. Jonkel, C.
Bear bibliography. Univ. Mont., Sch. For., Missoula, Unpubl.

Bibliography collected by Border Grizzly Project.
KEYWORDS: Bears.

8. Marsh, J.
1970. Bears and the public in our national parks. Can. Audobon 32(2):43-45.

Interviewed visitors to determine attitudes about bears. Suggests safer human ehavior and a more realistic assessment of bear hazards to reduce bear-man conflicts n parks.
KEYWORDS: Bear, danger, human attitudes, Canadian national parks.

89. Merrill, E. H.
1978. Factors affecting depredations on backcountry campgrounds by bears in Glacier National Park. Wildl. Soc. Bull. 6(3):123-126.

"Ecological and human-use parameters of 56 backcountry campgrounds in Glacier National Park were measured to determine factors which predispose these sites to bla bear *(Ursus americanus)* and grizzly bear *(U. arctos)* depredation. Examination of 50 bear incidents indicated that an unexpectedly high number of bear incidents occurred in deteriorated campgrounds in mature forest which were within 5 km of a developed a and which had large party limits and good fishing nearby. Changes in present campgr management are recommended to minimize bear-human conflicts." Recommendations inclu Locating campgrounds away from lake shores, major trail systems, and developed areas and intensive education about backcountry etiquette, especially garbage disposal.

KEYWORDS: Black bear, grizzly bear, campgrounds, recreation management, Glacie National Park.

90. Steinhart, P.
1978. Getting to know bruin better. Natl. Wildl. 16(5):20-27.

Popular review of current bear research. Quotes biologists who feel that bears national parks expect to eat visitors' food, and behave differently than bears in national forests. One bear biologist quoted believes the Yosemite bear population, especially in the high country, is unnaturally high because of the food obtained fro backpackers.

KEYWORDS: Black bear, backpackers.

91. East, B.
1978. Disneybeast or mankiller? Outdoor Life 162(4):81-83, 168, 170, 172, 1

Recites numerous accounts of black bears attacking man and, in some cases, eati the victims. Considers all bears, including male black bears, to be unpredictable and potentially dangerous. Suggests rekindling the fear of man in bears by regulate hunting.

KEYWORDS: Black bear, danger.

92. Gorsline, T.
1978. Maneating black bear! Outdoor Life 162(2):88, 100, 102, 104, 106, 108

Account of black bear killing and eating three boys. Quotes biologists who bel that as the number of man-bear contacts increase in areas like national parks where bears are protected, bears will lose their fear of man and regard nonviolent man as source of food.

KEYWORDS: Black bear, danger, Algonquin Park, Ontario.

93. Harms, D. R.
[In Press]. Black bear management in Yosemite National Park. 4th Int. Cong. Bear Research and Management, Feb. 21-24, 1977. Kalispell, Mont.

Management program to prevent man-bear interactions, includes: public informati and education, removal of artificial food sources, enforcement of regulations for feeding and food storage, control of problem bears, and monitoring of bear-human relationships.

KEYWORDS: Black bear, recreation management, Yosemite National Park.

94. Laycock, G.
1977. Everybody's favorite bear. Audubon 79(3):6-19.

Popular article on black bears which includes many stories of man-bear interactions from all over the United States.
KEYWORDS: Black bear.

95. Singer, F. J.
[In Press]. Black bear management in Great Smoky Mountains National Park. 4th Int. Conf. on Bear Research and Management. Feb. 21-24, 1977. Kalispell, Mont.

Bear management from 1964-1976 discussed. Bear incidents in Great Smoky Mountain National Park are correlated with habitat, physical features, visitor use, food storage, garbage storage, etc. Review of pertinent black bear research and management. (See Singer and Bratton 1976.)
KEYWORDS: Black bear, recreation management, wildlife management, Great Smoky Mountains National Park.

96. Singer, F. J., and S. P. Bratton.
1976. Black bear management in Great Smoky Mountains National Park. Uplands Field Res. Lab., Manage. Rep. 13. 34 p.

A review of black bear management in the Great Smoky Mountains National Park from 1964 to 1976. Most human injuries were associated with violations of Park Service regulations, particularly feeding of bears. Sows with cubs incurred the most injuries. Property damage caused by bears was predominantly in front country before 1973, but shifted to primarily back country after 1973, following a major increase in overnight backcountry use since 1970. Black bear damage incidents were positively correlated with the number of visitor nights at a backcountry site.
KEYWORDS: Black bear, wildlife management, Great Smoky Mountains National Park.

97. Whittaker, P. L.
1977. Black bear management in Great Smoky Mountains National Park. Rep. to the Superintendent, Great Smoky Mountains National Park. 14 p.

Describes bear incidents in Great Smoky Mountains National Park and management actions for the year 1977. The only management response to backcountry incidents was campsite closure. Problem bears near roads were translocated. Lithium chloride ($LiCl_2$) was fed to roadside bears to attempt to discourage roadside feeding by bears. It was unsuccessful. Improper food storage was the cause of most campground incidents.
KEYWORDS: Black bear, wildlife management, recreation management, Great Smoky Mountains National Park.

98. Bach, E., Jr.
1978. Backpacking in grizzly country. Backpacker 25:45-46, 66-68.

Lists precautions to be taken while backpacking in grizzly country. The author suggests that, to reduce risk, hikers learn about grizzly behavior, be alert, and avoid areas obviously used by bears; make their presence known; never hike alone; stay away from carrion; pick a good campsite and keep it free of food; and avoid all cosmetics; leave pets at home; give bears plenty of room; and stay cool in case of confrontation. Menstruating women should stay out of grizzly country.
KEYWORDS: Grizzly bear, backpackers, recreation management.

99. Chester, J. M.
[In Press]. Factors influencing human-grizzly bear interactions in a backcount setting. 4th Int. Conf. on Bear Research and Management, Feb. 21-24, 1977, Kalispell, Mont.

Seven species of wildlife including grizzly bears were studied for their interactions with humans in backcountry areas of Yellowstone National Park. Describes seasonal bear movements and human-bear encounter frequencies for on-trail travel and off-trail travel. Off-trail hikers were 3 to 4 times more likely to see grizzlies than people using trails. The greatest number of bear observations occurred during periods when bears were at low elevations.

KEYWORDS: Wildlife, grizzly bear, trail impacts, Yellowstone National Park.

100. Cole, G. F.
1974. Management involving grizzly bears and humans in Yellowstone National Park. Bioscience 24(1):1-11.

Describes management of bears and people in Yellowstone, which author felt reduce hazards "without deterring either grizzly reproduction or all human satifactions."

KEYWORDS: Grizzly bear, wildlife management, recreation management, Yellowstone National Park.

101. Elmork, K.
1978. Human impact on the brown bear population *(Ursus arctos* L.*)*. Biol. Conserv. 13:81-103.

The effects of human disturbance and activities on a remnant brown bear populatio in southern Norway was studied for 25 years. Negative correlations were noted between the number of bear observations and the density of roads. Fewer bears were observed in areas close to clusters of holiday cabins.

KEYWORDS: Brown bear, human impacts, Norway.

102. Faro, J., and S. Eide.
1974. Management of McNeil River State Game Sanctuary for nonconsumptive use of Alaska brown bears. *In* Proc. 54th Annu. Conf. Western Assoc. State Game and Fish Comm., p. 113-118. [Albuquerque, N. M., July 16-19, 1974.]

Increasing numbers of photographers at McNeil River Falls, Alaska, caused brown bears to modify the time and location of their fishing activities to avoid people. Unrestricted public use was incompatible with the intended purposes of the sanctuary and a limited permit system was initiated to regulate numbers of visitors during periods of bear concentrations.

KEYWORDS: Brown bears, photographers, recreation management, Alaska.

103. Frome, M.
1978. Teach people to respect bears. High Country News, Aug. 25, 1978. [Reprinted from Los Angeles Times.]

Expresses opinion that the federal government is not responsible for accidents occurring in national parks and wilderness areas, in particular injuries from grizzly bears. This means teaching people to respect bears and limiting or controlling human activity in bear country. The author feels that grizzlies and wilderness recreation are compatible.

KEYWORDS: Grizzly bears, recreation management.

04. Gilbert, B.
1976. The great grizzly controversy. Audubon 78(1):62-92.

Summarizes history of grizzly bear interactions with man from first white settlers o the present, including the Yellowstone Park bear management controversy. Suggests stablishing and managing some pieces of public land where grizzly take precedence over ll other interests.
KEYWORDS: Grizzly bear, wildlife management.

05. Herrero, S.
1970. Human injury inflicted by grizzly bears. Science 170:593-598.

Examines instances of human injury by bears in parks and makes suggestions on ways o minimize injuries. Notes that the public favors more effective management of people arbage, and bears.
KEYWORDS: Grizzly bear, danger, recreation management, wildlife management.

06. Herrero, S.
1970. Man and the grizzly bear (present, past, but future?). Bioscience 20(21):1148-1153.

Substantiates belief that grizzly bears and man can coexist in certain areas and that this coexistence is especially valuable in Glacier and Yellowstone National Parks. is coexistence is dependent on the behavior of people in these parks.
KEYWORDS: Grizzly bear, recreation management, Glacier National Park, Yellowstone National Park.

07. Herrero, S.
1978. The grizzly bear "stopper"--a feasible technology? Bear Biol. Assoc. 78(2):4-5.

Discusses a possible grizzly attractant that would hold bear's attention while the victim sneaks off, and grizzly "stoppers" such as electrical stun guns, knockout drugs, or Mace. Points out the dangers in these possibilities, and suggests the alternatives of: control of human use in prime grizzly habitat, education of recreationists concerning grizzly ecology and behavior, and acceptance of the fact that a few people will be injured by grizzlies each year.
KEYWORDS: Grizzly bear, wildlife management, recreation management.

108. Johnson, A. S.
1972. Man, grizzly and national parks. Natl. Parks Conserv. Mag. 46(2):10-15.

Article prompted by August 13, 1967, deaths of two girls in Glacier National Park. Traces man-bear interaction from Indians forward. Gives history of man's interaction with bears in Yellowstone National Park. Concludes the bear problem is tied to environmental pollution. Garbage-eating bears have lost fear of man in national parks. Describes National Park Service program to eliminate artificial foods from bears' diet. The goals are wild, independent populations of black and grizzly bears, greater safety for park visitors, and destruction of fewer bears.
KEYWORDS: Grizzly bear, recreation management, Yellowstone National Park.

109. Jonkel, C.
1977a. Clearcut logging, Cabin Creek, and the grizzly bear in southeastern British Columbia. Border Grizzly Project. Spe. Rep. 11, 11 p.

Grizzly is being detrimentally affected by: increased bear-man encounters, loss of habitat, and deterioration of natural bear behavior toward man. Management sugge tions include carefully controlled minimum development, protection of important habi road closures, improving public knowledge, and attitude about bears.
KEYWORDS: Grizzly bear, human impact, wildlife management, recreation manageme British Columbia, Montana.

110. Jonkel, C.
1977b. Living with grizzlies. Proc., Second Symp. on Endangered North Am. Species and Habitat. p. 133-137.[St. Louis, June 1-5, 1977.]

Ranchers and local people have coexisted with grizzlies in Montana. Grizzlies now threatened by: recent demands on resources from oil, gas and coal developments, subdivisions, pulp operations, ski developments, and recreationists with little knowledge of bears. Expresses need for more data on grizzly biology. Urges continu coexistence of grizzlies and man in Montana.
KEYWORDS: Grizzly bear, human impact, coexistence.

111. Jonkel, C., and C. Servheen.
1977. Bears and people. West. Wildl. 4(2):22-25.

Examples of successful coexistence of grizzlies with people. Suggest minimizin bear-people confrontations by restricting people in key areas of grizzly range when bears are using these areas and locating trails and camps away from these areas. Ru for backcountry users include: pack out garbage, cook and hang food away from sleepi areas, keep camp free of food debris, do not camp close to areas used by bears, stay alert on trails, learn about bear behavior, and do not take a dog with you unless it is trained to serve as an "early warning system." In case of an attack: climb a tre drop a pack or coat as distraction and move away, play dead, or if all else fails, fight.
KEYWORDS: Grizzly bear, coexistence, recreation management.

112. Jonkel, C., and N. McMurray.
1978. The Pacific Northwest Trail and grizzly bears. Border Grizzly Proj. Spec. Rep. 15, 6 p.

Recommendations for trail construction and management and behavior of users to reduce potential man-grizzly conflicts on the Pacific Northwest Trail. Guidelines could be applied elsewhere. Recommends that the trail avoid prime and precarious grizzly range with trail closures during critical seasons, and trail closures if: an animal carcass is near a trail, a female grizzly with cubs has been seen, or a grizzly with unusual behavior toward people is sighted. Generally the route of the trail and camping should occur away from areas normally used by grizzlies. Recommen rules for trail users, as in Jonkel and Servheen (1977).
KEYWORDS: Grizzly bear, trail impacts, recreation management.

113. Martinka, C. J.
1974. Preserving the natural status of grizzlies in Glacier National Park. Wildl. Soc. Bull. 2(1):13-17.

Reports on an integrated program of visitor information and travel restrictions Removal of unnatural food and bear control was accompanied by fewer injuries (0.2/ 1,000,000 visitors) and bear-caused deaths (1.0/year) than in previous years. Curre and future relationships between grizzlies, park visitors, and management programs a discussed.
KEYWORDS: Grizzly bear, recreation management, Glacier National Park.

14. Moment, G. B.
1968. Bears: The need for a new sanity in wildlife conservation. Bioscience 18(2):1105-1108.

Notes that bears interact with park visitors who are sightseeing, hiking, photoraphing, etc. Reviews injuries and deaths to humans by bears. Suggests that, because rizzlies are dangerous to people, we are under no moral obligation to maintain this pecies in the national parks.
KEYWORDS: Grizzly bear, danger, national parks.

15. Mundy, K. R. D., and D. R. Flook.
1973. Background for managing grizzly bears in the national parks of Canada. Can. Wildl. Serv. Rep. Ser. 22, 35 p.

Ecology of grizzly bears in Canadian parks is presented. Incidents of threats and ttacks on man in parks are described. Factors associated with bear belligerence nclude: surprising a bear at close range; approaching a bear in possession of a carcass, emales with young, or wounded bears; and bears habituated to associate man with ood or garbage. Management recommendations include: installing garbage incinerators way from human habitation centers; installing "bear-proof" garbage bins; picking up arbage every evening; issuing plastic bags to trail users to pack out unburned garbage; ocating campgrounds outside of favored grizzly habitat; informing the public about ears; restricting dogs; and advising hikers to make noise and avoid areas occupied y grizzlies.
KEYWORDS: Grizzly bear, danger, recreation management, Canadian national parks.

16. Riegelhuth, R.
1966. Grizzly bears and human visitation. M.S. thesis. Colo. State Univ., Ft. Collins. 80 p.

Roadless area nonhunting recreation at 1966 levels did not affect the well being f grizzly bear populations. With the exception of garbage dumps, grizzly use of isitor concentration sites did not increase as the numbers of visitors increased. ildland units larger than 1,000 square miles were much better for maintaining grizzly mbers than smaller areas. Incidence of unprovoked grizzly attack on nonhunting creationists was very rare.
KEYWORDS: Grizzly bear, recreation.

7. Russell, A.
1967. Grizzly country. 302 p. Alfred A. Knopf, New York.

A wilderness adventure book that includes stories about many grizzly-man teractions in the Canadian Rockies. Good information on the scope of potential grizzly havior.
KEYWORDS: Grizzly bear, Canada.

8. Russell, A.
1968. The people vs. the grizzlies. Field and Stream 62(11):60-61, 113-119, 151.

Review of grizzly bear attacks on two girls in Glacier National Park in 1967. ssell believes that grizzlies and people can coexist compatibly if the bears have not en conditioned to feed on garbage.
KEYWORDS: Grizzly bear, danger, coexistence.

119. Schallenberger, A.
[In Press]. Review of oil and gas exploitation impacts on grizzly bears. 4th Int. Conf. on Bear Research and Management, Feb. 21-24, 1977. Kalispell, M

Present conflicts with grizzly need to be determined before gas and oil explorat begins. The greatest impacts appear to be the construction of roads in previously unroaded areas and the increased use of land by people. Suggests restrictions in development until adequate grizzly management data are available.
KEYWORDS: Grizzly bear, human impact, Montana.

120. Schneider, B.
1977. Where the grizzly walks. 191 p. Mountain Press Publishing, Missoula,

Concerned with history of the relationship of the grizzly bear with man and how this affects the future of the bear. Emphasizes the effects of development on the be and what needs to be done to control development on grizzly habitat.
KEYWORDS: Grizzly bear, human impacts.

121. Servheen, C. W.
1978. The grizzly bear in the Rattlesnake Mountains. *In* Annual report border grizzly project. p. 3-15. C. Jonkel. School of For., Univ. Mont. 256 p. Missoula.

Contains section on management of recreation in grizzly habitat in the Rattlesna drainage in Montana, with the objective of positive benefits to both bear and man. Suggests that if recreational use of high country increases it may be necessary to cl trails or lakes frequently used by a grizzly, limit camping to certain areas, relocat trails and campgrounds, limit use of some areas during certain seasons, and provide bear country camping instructions at trail heads.
KEYWORDS: Grizzly bear, recreation management, trail impacts.

122. Stuart, T. W.
[In Press]. Exploration of optimal backcountry travel patterns in grizzly bea habitat. 4th Int. Conf. on Bear Research and Management. Feb. 21-24, 1977. Kalispell, Mont.

Parametric linear programming was used to quantify trade-offs among five managem objectives: three measures of trail-related contact between grizzly bears and man (dangerous, nondangerous, total), a measure of solitude at backcountry campsites, and the volume of backcountry overnight use. This system could be used to help people pl trips to meet their objectives while encouraging a pattern of use that results in few grizzly conflicts.
KEYWORDS: Grizzly bear, trail impacts, Glacier National Park.

123. Stuart, T. W.
1978. Management models for human use of grizzly bear habitat. Trans. North Wildl. and Nat. Resour. Conf. 43:434-441.

Management models were developed for overnight backcountry trips in Glacier National Park. Models are linear programs in which the variables are backcountry ove night trips during specific time periods. Solutions to the models identify backcount overnight use patterns that are optimal for various combinations of management objectives. Essentially the same as the preceding paper.
KEYWORDS: Grizzly bear, trail impact, Glacier National Park.

124. Taylor, R.
[In Press]. Certain aspects of behavior and management of the grizzly bear in Montana. 4th Int. Conf. on Bear Research and Management. Feb. 21-24, 1977. Kalispell, Mont.

Describes circumstances of the deaths of grizzly bears between 1958 and 1963. Outside of national parks, bears do not have an opportunity to develop bad habits, probably due to hunting and protection of property by private citizens.
KEYWORDS: Grizzly bears, wildlife management, Montana.

25. Davids, R. C.
1978. Polar bears aren't pets, but this town is learning how to live with them. Smithsonian 8(11):70-79.

Describes the positive attitudes of the people of Churchill, Manitoba, toward polar bears, and the manner in which coexistence occurs. Churchill is on a polar bear migration route. Because these bears are threatened with extinction, the people of Churchill are determined to coexist with the bears in spite of frequent encounters.
KEYWORDS: Polar bears, coexistence, Hudson Bay.

Cats

26. Culbertson, N.
1977. Status and history of the mountain lion in the Great Smoky Mountains National Park. USDI Natl. Park Serv., Uplands Field Res. Lab., Great Smoky Mountains Natl. Park Manage. Rep. 15, 70 p.

Lion sightings are increasing in the Great Smoky Mountains National Park. As nteractions with humans increase lion attacks on people can be expected to increase. The most important factor determining the future of lions in this area will be the public's attitude toward lions. Hunters, especially those hunting with dogs, may pose a threat to lions in this area.
KEYWORDS: Mountain lions, Great Smoky Mountains National Park.

27. Saile, B.
1977. Cougar attacks: new crisis for the big cats. Outdoor Life 160(2):66-68, 126, 127, 128.

Mountain lions in the West are stable or increasing even though human populations re increasing and encroaching on mountain lion habitat. The number of mountain lion ttacks on humans has increased in recent years.
KEYWORDS: Mountain lions, danger.

28. U.S. Fish and Wildlife Service, Region 1.
1976. Transactions of the mountain lion workshop of the western states and Canada. [Sparks, Nevada, Jan. 13, 14, 1976.] 190 p.

The number of lion attacks on humans has recently increased significantly in ritish Columbia. This is thought to be the result of increased lion-human interactions. ions are living in areas of human density such as subdivisions. Lion attacks on humans ave also increased suddenly in New Mexico.
KEYWORDS: Mountain lions, danger, British Columbia, New Mexico.

Ungulates

(Also see reference numbers 10-13, 19, 188)

Elk

(Also see reference numbers 4, 21, 30, 32, 33, 154, 184, 186, 190, 223)

129. Altman, M.
1956. Patterns of herd behavior in free-ranging elk of Wyoming. Zoologica (
41:65-71.

Account of free-ranging elk behavior. Compares behavior of disturbed and undisturbed elk herds during rut. Describes reactions of previously undisturbed elk to t opening of hunting season.
KEYWORDS: Elk, human disturbance, Wyoming.

130. Altman, M.
1958. The flight distance in free-ranging big game. J. Wildl. Manage. 22(2)
207-209.

The distance at which free-ranging elk and moose would flee from humans varied habitat, social groupings, nutrition, reproductive status, and specific experience o individual animals of the group.
KEYWORDS: Elk, moose, flight distance.

131. Lieb, J. W.
1973. Social behavior in Roosevelt elk cow groups. M.S. thesis. Humboldt
State Univ., Arcadia, Calif. 82 p.

In Prairie Creek Redwoods Park, increasing human disturbance during the early summer caused increased aggression among members of cow elk groups. This may be due to a decrease in tolerance by elk for each other under insecure conditions. Rutting bulls reacted aggressively towards approaching humans in 13 of 17 cases of human disturbance. Suggests that human disturbance should be controlled, especially durin the reproductive portions of the year.
KEYWORDS: Elk, human disturbance, California.

132. Lieb, J. W., and A. S. Mossman.
1974. Elk drowning. Murrelet 55(3):39-40.

A bull elk, unfamiliar with inland escape routes through cliffs, fled from researcher into the ocean and drowned. Also cites another similar case. Suggests th frightened animals that are not familiar with alternative escape routes may flee int water. People should avoid disturbing frightened elk near large or rough bodies of water when inland escape appears blocked.
KEYWORDS: Elk, human impact, California.

133. Lieb, J. W., and A. S. Mossman.
1966. Final progress report on Roosevelt elk in Prairie Creek Redwoods State Park. Calif. Dep. Parks and Recreat., Interagency Agreement 4-05094-025, 8 p.

In response to human disturbance, elk moved from primary to secondary forage areas and cows with young calves moved away from the central part of their home ranges. Play and rutting activity were disrupted by human disturbance. Recommends reducing human disturbance at certain locations in order to retain elk herds in these areas, posting signs explaining why visitors should not disturb elk (especially during rutting and calving), and enforcement of regulations (including elimination of poaching).
KEYWORDS: Elk, human disturbance, recreation management, California.

134. Morgantini, L. E., and R. J. Hudson.
1979. Human disturbance and habitat selection in elk. *In* Symposium on elk ecology and management. p. 132-139. [Laramie, Wyoming, April 3-5, 1978.]

Habitat selection by elk was not simply related to weather conditions or available food. Passive harassment resulting from human activities (vehicular and hunting) reduced elk use of open grassland (transected by roads) and caused overgrazing of marginal areas (away from roads). This may be especially hard on elk during severe winters when energy budgets are stressed.
KEYWORDS: Elk, winter, human disturbance, Alberta.

35. Shultz, R. D., and J. A. Bailey.
1978. Responses of national park elk to human activity. J. Wildl. Manage. 42(1):91-100.

Responses of elk to human activities near a road were quantified for fall, winter, nd spring in Rocky Mountain National Park. These elk, which experienced little or o hunting, were not significantly disturbed by normal on-road visitor activities.
KEYWORDS: Elk, human disturbance, winter, Rocky Mountain National Park.

36. Ward, A. L.
1973. Elk behavior in relation to multiple uses on the Medicine Bow National Forest. Proc., 53rd Conf. West. Assoc. of State Game and Fish Commissioners. p. 125-139.

Telemetry was used to monitor elk behavior in relation to multiple use of the orest. Elk and cattle were compatible where there was adequate food. Elk preferred o be at least one-half mile from people who were engaged in out-of-vehicle activities.
KEYWORDS: Elk, radio telemetry, human disturbance, Wyoming.

37. Ward, A. L., J. J. Cupal, A. L. Lea, C. A. Oakley, and R. W. Weeks.
1973. Elk behavior in relation to cattle grazing, forest recreation and traffic. Trans. North Am. Wildl. and Nat. Resour. Conf. 38:327-337.

Telemetered elk in Wyoming study area preferred to be one-half mile distant from eople who were camping, picnicking, and fishing. Suggests that in planning recreation acilities in elk habitat, people concentration areas should be one-half mile from elk eeding sites and provide adequate cover buffer zones.
KEYWORDS: Elk, recreation management, radio telemetry, Wyoming.

Mule Deer

(See reference numbers 3, 4, 18, 30-33)

White-Tailed Deer

138. Behrend, D. F., and R. A. Lubeck.
1968. Summer flight behavior of white-tailed deer in two Adirondack forests. J. Wildl. Manage. 32(3):615-618.

Distances at which antlered deer took flight were significantly longer on hunted than unhunted areas.
KEYWORDS: White-tailed deer, flight distance.

139. Moen, A. N.
1976. Energy conservation by white-tailed deer in the winter. Ecology 57(1): 192-198.

Analyzes energy-conserving behavioral adaptations of white-tailed deer in northwestern Minnesota during the winter. Energy conservation of up to 1,000 Kcal/day for a 60 kg deer can result from reduced activity levels (seeking level land and lesser snow depth, walking slowly, etc.). Winter harassment of deer by dogs or snowmobile traffic is detrimental to these adaptations.
KEYWORDS: White-tailed deer, winter, harassment, Minnesota.

140. Moen, A. N.
1978. Seasonal changes in heart rates, activity, metabolism, and forage intak of white-tailed deer. J. Wildl. Manage. 42(4):715-738.

Annual cycles of white-tailed deer metabolism were studied. Deer metabolism is the lowest in the winter and the highest during the summer. This is an adaptation fo energy conservation because the animal's needs are lowest when the range resources ar reduced. The author concludes from this and earlier work that the white-tailed deer is well adapted "for energy conservation in the winter and any disturbance that alter this mode of life is a potential depressant of productivity."
KEYWORDS: White-tailed deer, winter.

Moose

(Also see reference numbers 4, 30, 31, 130)

141. Denniston, R. H.
1956. Ecology, behavior and population dynamics of the Wyoming or Rocky Mounta moose. Zoologica (N.Y.) 41:105-118.

Suggests that the success of moose in the Rocky Mountain area may be due in part to their adaptability to human influences. Moose will often tolerate a quiet, unobstrusive observer, but may be frightened by an unsuccessful attempt to stalk. Threa behavior and attacks may be elicited from cows with calves or animals in threatened situations. Most moose-human encounters occur in the winter.
KEYWORDS: Moose, Wyoming.

142. de Vos, A.
1958. Summer observations on moose behavior in Ontario. J. Mammal. 39(1):128-139.

Short section on behavior after disturbances. Behavior of disturbed moose is ver subtle, giving the impression of no alarm. Often they move slowly until they reach cover where they may break into a run, indicating more fear than initially exhibited.
KEYWORDS: Moose, flight distance, Ontario.

43. Geist, V.
1963. On the behavior of the North American moose (*Alces alces andersoni* Peterson 1950) in British Columbia. Behavior 20:377-416.

Calf and yearling moose are sometimes quite tame when adults are absent. The sight f man at close range causes most animals to run; however, there is considerable variaion among individual moose. Cites cases where moose did not take flight even when one f the group was shot. Intense feeding often occurs after disturbance has passed.
KEYWORDS: Moose, human disturbance, British Columbia.

44. LeResche, R. E.
1966. Behavior and calf survival in Alaska moose. M.S. thesis. Univ. Alaska, Fairbanks. 85 p.

Reactions of moose to human disturbance ranged from flight, through slowly drifting way, to seeming disinterest. Cows with calves were the most wary.
KEYWORDS: Moose, human disturbance, Alaska.

45. McMillan, J. F.
1954. Some observations on moose in Yellowstone Park. Am. Midl. Nat. 52(2):392-399.

In areas of heavy tourist pressure, moose develop considerable tolerance for human isturbance, moving slowly and returning soon. In a control area visitor disturbance aused moose to run from area and not return until at least the next day.
KEYWORDS: Moose, human disturbance, Yellowstone National Park.

46. Stringham, S. F.
1974. Mother-infant relations in semi-captive Alaskan moose *(Alces alces, gigas)*. M.S. thesis. Univ. Alaska, Fairbanks. 140 p.

Reactions of moose to the researcher are described in methods section. Moose abituated to researcher but were disturbed by persistence of researcher once they were ware of his presence.
KEYWORDS: Moose, habituation.

Caribou

Also see reference number 31)

47. Bergerud, A. T.
1971. The role of the environment in the aggregation, movement and disturbance behavior of caribou. *In* The behavior of ungulates and its relation to management, Vol 2. p. 530-541. V. Geist and F. Walther, eds. Int. Union Conserv. Nat. Resour. Publ. New Series 24, Morges, Switzerland.

Discusses caribou behavioral adaptations and adaptability. The author believes aribou can live near man if man permits it. Suggests that, in populations not subject o natural predation, wildlife managers should harvest unwary animals if they want nimals that are difficult to hunt, and harvest wary animals if they desire a population hat can be seen in a park.
KEYWORDS: Caribou, wildlife management.

148. Calif, G. W.
1976. Numbers beyond counting, miles beyond measure. Audubon 78(4):42-61.

Considers the physical effects of the Alaskan pipeline on caribou migration as well as effects of construction workers in terms of more roads, aircraft, snowmobiles, hunting, and general harassment. Author believes caribou can live near man if man permits it.
KEYWORDS: Caribou, human impact.

149. de Vos, A.
1960. Behavior of barren-ground caribou on their calving grounds. J. Wildl. Manage. 24:250-258.

Contains section on reaction of caribou to humans. Flight distance varied with environmental conditions and band size. Cows with calves were more alert and ran farther than cows without calves.
KEYWORDS: Caribou, flight distance.

150. Freddy, D. J.
1973. The status and management of the Selkirk caribou herd 1973. M.S. thesis Univ. Idaho, Moscow. 132 p.

Selkirk caribou herd's future is precarious because of its small size (about 20-25 animals). Sustaining this herd depends on maintaining movement routes, maintaining mature subalpine fir-Engelmann spruce winter habitat, and controlling human-induced mortality. Illegal hunting and road kills were the only sources of mortality during the study. Management recommendations are included.
KEYWORDS: Caribou, wildlife management, human impact.

151. Stelfox, J. G., and J. A. Bindernagel.
1978. Caribou behavior in relation to human-elk-wolf influences: Jasper National Park 1971-1974. Prepared for Parks Canada by the Canadian Wildl. Serv., Edmonton. 59 p.

Examines encroachment of elk and hikers onto caribou ranges in Jasper. Caribou, especially cows, are most vulnerable to harassment in spring and summer when humans an caribou both make greatest use of alpine tundra. Management suggestions include placi hiking trails away from major caribou ranges and/or restricting hikers during critical calving periods, and minimizing harassment at natural licks and on calving, rearing, and rutting ranges.
KEYWORDS: Caribou, recreation management, trail impacts, Jasper National Park.

Pronghorn

(See reference numbers 32, 33)

Mountain Goat

152. Bansner, U.
1976. Mountain goat-human interactions in the Sperry-Gunsight pass area, Glacie National Park. Senior thesis, Univ. Mont., Missoula. 46 p.

Describes attraction of salt, from human and horse urine and from blasting, in lur goats to areas of human concentration. Notes potential danger to visitors from habituated goats. Management suggestions include reducing the salt from urine by improving sanitary facilities, blasting only when manpower is inadequate, and informing users about mountain goat ecology and behavior so they are aware of potential safety hazards.
KEYWORDS: Mountain goat, danger, salt, recreation management, trail impacts, Glacier National Park.

153. Holroyd, J. C.
1967. Observations of Rocky Mountain goats on Mount Wardle, Kooteney National Park, B. C. Can. Field-Nat. 81:1-22.

Reports reaction of goats to the author. Response varied according to season, size of group, and circumstances under which they were encountered. Reactions ranged from flight to charges.

KEYWORDS: Mountain goat, British Columbia.

154. Singer, F. J.
1975. Behavior of mountain goats, elk and other wildlife in relation to U.S. Highway 2, Glacier National Park. Glacier Natl. Park, West Glacier, Mont. 96 p.

Analyzes the effect of U.S. Highway 2 with its associated vehicles and people on various wildlife species, especially goats using salt lick, in order to form a basis for options in proposed highway reconstruction. Considers behavioral characteristics of goats, elk, grizzly, and wolves as well as humans in recommending highway construction alternatives. This paper demonstrates practical application of knowledge of animal behavior to a management problem.

KEYWORDS: Mountain goat, elk, grizzly bear, wolves, highway, animal behavior, wildlife management, Glacier National Park.

155. Singer, F. J.
1978. Behavior of mountain goats in relation to U.S. Highway 2, Glacier National Park, Montana. J. Wildl. Manage. 43(2):591-597.

The behavior of mountain goats crossing a highway to visit a natural mineral lick was studied. Groups of goats were more successful at crossing the highway than individual goats. Groups led by a nanny with kid at side had the most success at crossing. Peak use of the lick (July and August) was also the peak in visitor activity. Goat use of the lick during this time was primarily at night, whereas use of an undisturbed lick did not follow this pattern. Because of disturbance during crossings and the potential for goat-car collisions, a goat crossing and restriction of visitors from crossing area was recommended. The proposed goat crossing is an underpass in the main goat crossing area. Goat movements in other areas would be restricted by fencing and a bin wall. Lead-in fences, protective conifer cover, and trails will help encourage goat use of structures.

KEYWORDS: Mountain goats, highway, wildlife management, Glacier National Park.

156. Smith, B. L.
1976. Ecology of Rocky Mountain Goats in the Bitterroot Mountains, Montana. M.S. thesis. Univ. Mont., Missoula. 189 p.

Recommends leaving land adjacent to goat winter ranges roadless to prevent overharvesting accessible herds and to reduce harassment. Makes management recommendations concerning buffer zones, logging, hunting, and roads.

KEYWORDS: Mountain goats, roads, Montana.

Mountain Sheep (Bighorn)

(Also see reference numbers 4, 14)

157. Blong, B.
1967. Desert bighorn and people in the Santa Rosa Mountains. Calif. Nev. Section Meeting, Wildl. Soc. Trans., p. 66-70.

Human disturbance and habitat loss due to urban development threaten the survival of desert bighorn in the Santa Rosa Mountains of California.

KEYWORDS: Bighorn sheep, human impact, California.

158. DeForge, J. R.
1972. Man's invasion into the bighorn's habitat. Trans. Desert Bighorn Counc. 16:112-116.

Man's invasion into bighorn sheep habitat in the San Gabriel Mountains in the fo of logging, vacationers, motorcyclists, and hunters has caused a reduction in the numb of sheep using the area. Expresses concern that this may be occurring in other areas sheep habitat.
KEYWORDS: Bighorn sheep, human impact, California.

159. DeForge, J. R.
1976. Stress: Is it limiting Bighorn? Trans. Desert Bighorn Counc. 20:30-31.

Man's impact on sheep habitat is causing stress that appears to be the major limiting factor in the bighorn's struggle for survival.
KEYWORDS: Bighorn sheep, human impact.

160. Dixon, J. S.
1936. The status of the Sierra bighorn sheep. Proc. First North Am. Wildl. Conf. p. 641-643.

The author believes that increase in recreational camping, illegal shooting, and grazing of domestic sheep on bighorn summer ranges were primary factors limiting bighorn sheep.
KEYWORDS: Bighorn sheep, human impact.

161. Dunaway, D. J.
1970. Status of bighorn sheep populations and habitat studies on the Inyo National Forest. Trans. Desert Bighorn Counc. 14:127-146.

Suggests that increased recreational use of sheep ranges has resulted in the decline of sheep use. Off-trail backpacking in alpine areas should be monitored for its effects on sheep.
KEYWORDS: Bighorn sheep, backpackers, California.

162. Dunaway, D. J.
1971a. Bighorn sheep habitat management on the Inyo National Forest, a new approach. Trans. Desert Bighorn Counc.15:18-23.

Human use of bighorn sheep ranges seems to be a major factor in the decline of sheep populations in the Sierra Nevadas during the past 20 years. Proposes a bighorn sheep zoological area to include the two largest herds of bighorn remaining in the Sierras. Management objectives are to protect and maintain bighorn habitat and limit human use in key areas.
KEYWORDS: Bighorn sheep, human disturbance, wildlife management, California.

163. Dunaway, D. J.
1971b. Human disturbance as a limiting factor of Sierra Nevada bighorn sheep. Trans. North Am. Wild Sheep Conf. 1:165-173.

Examines the impact of predation, grazing competition, disease, and parasites on bighorn sheep and concludes human disturbance and loss of habitat are the major causes for the population decline. The author recognizes that this may be an incorrect conclusion, but because some bighorn populations are already limited, every effort should be made to protect these animals.
KEYWORDS: Bighorn sheep, human impact, Sierra Nevada.

164. Elder, J. M.
1977. Human interactions with Sierra Nevada bighorn sheep: the Mount Baxter herd. M.S. thesis. Univ. Mich., Ann Arbor. 102 p.

Describes interaction of sheep with backpackers and climbers. Climbers had greatest potential effects on sheep. Questions the effects on sheep of allowing stock and pets or numbers of people greater than 1976 levels in the Mount Baxter area.
KEYWORDS: Bighorn sheep, backpackers, Sierra Nevada.

165. Geist, V.
1975a. Bighorn sheep biology. Wildl. Soc. News 136:61.

Points out the value of older rams in sheep populations. Also discusses effects of harassment, concluding that "the worst combination of harassment is hunting combined with hiking, particularly camera-happy hiking, for the second reinforces what the first one teaches--flight from humans".
KEYWORDS: Bighorn sheep, harassment, hikers, photographers.

.66. Geist, V.
1975c. On the management of mountain sheep; theoretical considerations. *In* The wild sheep in modern North America. p. 77-105. J. B. Trefethen, ed. Boone and Crockett Club. 302 p. Winchester Press, New York.

Discusses methods of managing sheep populations depending on the management objec-ives of consumptive or nonconsumptive uses. Describes deleterious effects of hunting combined with hiking on sheep populations. In unhunted populations, habituation of sheep can insure continued use of best range and still allow public viewing. Emphasizes he need for public education so that people will know what to expect from the animals, as well as how they should behave around the animals.
KEYWORDS: Bighorn sheep, Dall sheep, wildlife management, habituation, harassment, education.

67. Graham, H.
1966. Multiple use coordination on the San Gorgino bighorn unit. Trans. Desert Bighorn Counc. 10:71-76.

Recommendations for multiple-use coordination with bighorn sheep management in the San Gorgino bighorn unit. Discusses road, trail, and campsite locations in relation to reas used by bighorns.
KEYWORDS: Bighorn sheep, recreation management, trail impacts, California.

68. Hansen, C. G.
1971. Overpopulation as a factor in reducing desert bighorn populations. Trans. Desert Bighorn Counc. 15:46-52.

Discusses human encroachment on bighorn habitat forces sheep into smaller areas and poorer, more remote ranges. The effects on sheep may be similar to overpopulation stress that may cause natural population control.
KEYWORDS: Bighorn sheep, human impact.

169. Hicks, L. L.
1977. Human disturbance of the Mount Baxter herd of Sierra Nevada bighorn she
M.S. thesis. Univ. Mich., Ann Arbor. 57 p.

Sheep reactions to humans depend on herd size, distance to people, and relative position of people on the mountain. Humans approaching from above caused more distur ance than those approaching from below. Small groups of sheep were more susceptible to disturbance than large groups. Management recommendations included rerouting trai away from areas of concentrated sheep use and restriction of some forms of human activity.
KEYWORDS: Bighorn sheep, human disturbance, recreation management, trail impact Sierra Nevada.

170. Horejsi, B.
1976. Some thoughts and observations on harassment and bighorn sheep. *In* Nor
Wild Sheep Counc. Proc. p. 149-155. Jackson, Wyo.

Coal exploration and development, ski resorts, and increasing outdoor recreation are causing year-round contact of man and sheep. The combination of hunting (resulti in fear of man) and continuous recreational use of sheep range result in year-round harassment of sheep. If the integrity of sheep populations is to be maintained, then research and regulations need to be aimed at minimizing or eliminating harassment.
KEYWORDS: Bighorn sheep, harassment.

171. Light, J. T. R.
1971. An ecological view of bighorn habitat on Mount San Antonio. Trans. Nort
Am. Wild Sheep Conf. 1:150-157.

Bighorn use of habitat does not occur where human use is heavy. High-value habi heavily used by humans will exclude bighorn use. Bighorns tolerate only limited huma disturbance before being driven from home ranges. Ewes with young are less tolerant of human approaches than individual ewes and rams.
KEYWORDS: Bighorn sheep, human disturbance, California.

172. MacArthur, R. A., R. H. Johnston and V. Geist.
[In Press]. Factors influencing heart rate in free-living bighorn sheep: a
physiological approach to the study of wildlife harassment. Can. J. Zool.

KEYWORDS: Bighorn sheep, heart rate telemetry, harassment.

173. McCann, L. J.
1956. Ecology of the mountain sheep. Am. Midl. Nat. 56(2):297-325.

Contains brief section on wariness. The ewes and young were tolerant of human presence during the study. Mature rams took flight at the sight of man. This was considered to be the result of hunting pressure on rams.
KEYWORDS: Bighorn sheep, Wyoming.

174. Nelson, M.
1966. Problems of recreational use of game ranges. Trans. Desert Bighorn Coun
10:13-20.

Discusses the detrimental effects of different forms of recreation on bighorn she and the ability of sheep to adapt. Suggests need to classify critical game range land for lasting protection and minimum public interference.
KEYWORDS: Bighorn sheep, recreation.

175. Tevis, L., Jr.
1959. Man's effect on bighorn in the San Jacinto-Santa Rosa Mountains. Desert Bighorn Counc. Trans. 3:69-74.

Discusses the effects of man on the bighorn sheep in the Palm Springs resort area from pre-white man to present. Makes some management suggestions to reduce impact and suggests research on the effects of subdivision of the sheep range.
KEYWORDS: Bighorn sheep, human impact, California.

176. Van Den Akker, J. B.
1960. Human encroachment on bighorn habitat. Desert Bighorn Counc. Trans. 3:38-40.

The author feels that the future welfare of the bighorn will be determined by the control of human encroachment on bighorn habitat. Singly, most types of encroachment (hiking, ORV's, introduction of domestic animals to compete for range and water, military activities, highways, and reservoirs) may not eliminate bighorns, but the uncontrolled cumulative effect has that potential.
KEYWORDS: Bighorn sheep, human impact.

177. Wehausen, J. D., L. L. Hicks, D. P. Garber, and J. Elder.
1977. Bighorn sheep management in the Sierra Nevada. Trans. Desert Bighorn Counc. 21:30-32.

Zoological areas were established to protect bighorn sheep from the assumed adverse effects of human disturbance. Subsequent research suggested that human disturbance was not as significant a factor as supposed. Management policies are being revised to allow relaxation of the rules for visitors while keeping bighorn management as first priority. When dealing with jeopardized populations, the authors feel prompt conservation action should be taken on the basis of untested hypotheses. If these hypotheses are proven inaccurate, management may be altered.
KEYWORDS: Bighorn sheep, recreation management, human disturbance, Sierra Nevada.

178. Welles, R. E., and F. B. Welles.
1961. The bighorn of Death Valley. Fauna of the National Parks of the U.S. Fauna Series No. 6. U.S. Govt. Printing Off. 242 p. Washington, D.C.

Reports on an 8-year study of desert bighorn in Death Valley National Monument. Deliberate attempts of humans to conduct themselves within limits acceptable to bighorn led to tolerance of human presence. Describes influence of herd leader on acceptance of humans. Concludes that "only unchecked human encroachment appears actually to threaten the future status of the bighorn."
KEYWORDS: Bighorn sheep, habituation, human impact, Death Valley National Monument.

179. Wilson, L. D.
1969. The forgotten desert bighorn habitat requirement. Trans. Desert Bighorn Counc. 13:108-113.

Points out that although some bighorn sheep do tolerate man, these are actually individual exceptions. Bighorn tend to be intolerant of people, autos, livestock, and other ungulates. If they are to survive they must be given higher priorities in land-use planning.
KEYWORDS: Bighorn sheep, human impact.

180. Woodward, T. N., R. J. Gutierrez, and W. H. Rutherford.
1974. Bighorn ram production, survival and mortality in south-central Colora
J. Wildl. Manage. 38(4):771-774.

In the Sangre de Cristo range in Colorado, human pressures have forced mountain bighorn into lambing ranges at higher elevations where extended bad weather can caus 80 percent incidence of pneumonia in lambs and a steady decline in population.
KEYWORDS: Bighorn sheep, human impact, Colorado.

Dall Sheep

(Also see reference numbers 1, 31, 85, 166)

181. Anderson, R.
1971. Effects of human disturbance on Dall sheep. Alaska Coop. Wildl. Res.
Quart. Rep. 22(3):23-27.

Dall sheep in Atigun Canyon in the Brooks Range were studied because of the pos bility of this route for the Trans-Alaska pipeline. Describes reaction of sheep to people on the ground and to aircraft. Suggests restricting flying and construction t reduce harassment of sheep, especially early in season, during lambing, and near min licks. Recommends routing pipeline elsewhere.
KEYWORDS: Dall sheep, wildlife management, salt, human impact, Alaska.

182. Price, R.
1972. Effects of human disturbance on Dall sheep. Alaska Coop. Wildl. Res.
Unit. Quart. Rep. 23(3):23-28.

Dall sheep in Atigun Canyon in the Brooks Range were studied because of the possibility of this route for the Trans-Alaska pipeline. Sheep were disturbed by helicopters, but long term effects are not known. Suggests that aircraft pilots using th canyon be made aware of the possible consequences of disturbance. Recommends no on-ground activities in the canyon from mid-May thru early July because of lambing, and carefully regulated activities after that. Mineral lick areas may need special prote tion to prevent harassment of sheep using them.
KEYWORDS: Dall sheep, human impact, wildlife management, salt, Alaska.

Harassment Reduction Literature

WILDLIFE MANAGEMENT AND HABITAT MANIPULATION

(Also see reference numbers 12, 13, 16, 17, 20, 23, 30, 55, 60, 66, 68-70, 72-75, 79, 82, 83, 89, 91, 95-97, 100, 102, 104, 105, 107, 109, 147, 150, 154-156, 164, 166, 16 175, 181)

183. Allen, D.
1966. The preservation of endangered habitats and vertebrates of North Americ
In Future environments of North America, p. 22-37. F. Frazer Darling and John Milton, eds. The Natural History Press, Garden City, N.Y.

Cites classic examples of animals whose existence has been jeopardized by man o his actions, and reports on what has been done to better manage individual wildlife populations.
KEYWORDS: Wildlife, human impact.

184. Anderson, E. W., and R. T. Scherzinger.
1975. Improving quality of winter forage for elk by cattle grazing. J. Range Manage. 28(2):120-125.

Cattle grazing was manipulated (area, time of year, and numbers) to increase forage quality for wintering elk on a wildlife management area in northeastern Oregon. (In a period without cattle grazing, forage had become rank and of low quality for wintering elk.) The success of this system was also attributed to other factors, among which were: the creation of new ponds and salting for better distribution of grazing, and closure of the area from December 1 to May 1 to prevent harassment of elk by snowmobilers.

KEYWORDS: Elk, winter, wildlife management, habitat modification, human impact, Oregon.

185. Bart, J.
1977. Impact of human visitations on avian nesting success. Living Bird. 16:187-192.

Field observers studying nesting birds may lead predators to nests. This study documents increased predation on the day after a human visit to nests of robins, bluebirds, and mourning doves. Recommends methods of making trails so that predators are not led directly to nests.

KEYWORDS: Robin, bluebird, mourning dove, birdwatching, human impact.

186. Batcheler, C. L.
1968. Compensatory responses of artificially controlled mammal populations. N.Z. Ecol. Soc. Proc. 15:25-30.

Red deer were hunted and harassed in areas of good habitat where deer caused damage. Deer displaced to areas of poor habitat were left undisturbed. These deer became nocturnal and experienced reduced reproductive rates, and lower fat deposition. They did not return to good habitat after cessation of hunting and harassment.

KEYWORDS: Red deer, harassment, New Zealand.

187. Batten, L. A.
1977. Sailing on reservoirs and its effects on water birds. Biol. Conserv. 11:49-58.

Water bird populations are increasingly disturbed by the use of reservoirs by recreationists. Suggests reserving a large, shallow, marshy, portion of a reservoir for birds, with no boat access allowed.

KEYWORDS: Water birds, water recreation, human disturbance.

188. Cowan, I. McT.
1971. Management implications of behavior in the large herbivorous mammals. *In* The Behavior of Ungulates and its Relation to Management, vol. 2. p. 921-934. V. Geist and F. Walther, eds. International Union for Conservation of Nature. No. 24, Morges, Switzerland.

This is a substantial literature review relating animal behavior to possible management techniques. Cites many examples of animal behavior and animal learning that could relate to possible management techniques. Suggests that a thorough knowledge of species-specific behavior allows managers to adjust management practices to fit objectives. Comments on the impacts on nonconsumptive users on wildlife. Suggests protection of females with young, breeding grounds, and birthing areas. Suggests educating visitors to behave appropriately in areas where animals are habituated.

KEYWORDS: Ungulates, animal behavior, wildlife management, education.

189. Geist V.
1978. Behavior. *In* Big Game of North America; ecology and management. p. 283
296. J. L. Schmidt and D. L. Gilbert, eds. Wildl. Manage. Inst. 494 p.

A thorough treatment of the significance of animal behavior in the management of wildlife. Examines the effects of harassment on wild animals. Proposes teaching game animals to accept the presence of humans. Humans must also be taught not to approach wild animals too closely.
KEYWORDS: Animal behavior, harassment, wildlife managment.

190. Geist, J. M., P. J. Edgerton, and G. S. Stickler.
1974. 'Yukky to Yummy'--with fertilizers. Rangemen's J. 1(2):39-41.

An experiment on the effects of fertilizer on timothy seeded in a clearcut resulting in elk eating most of the fertilized grass. Potential benefits of fertilizer incl attracting elk to public viewing areas, relieving grazing pressure on native species o vegetation, and improving the nutrition of elk during calving. The authors suggest more research on fertilizer as a management tool.
KEYWORDS: Elk, fertilizer, habitat modification, Oregon.

191. Hendee, J. C., G. H. Stankey, and R. C. Lucas.
1978. Wilderness management. U.S. Govt. Print. Off. 381 p. Washington, D.C.

Summary and synthesis of information pertinent to management of the National Wilderness Preservation System. Chapter 11 by John Hendee and Clay Schoenfeld identifies wilderness wildlife values and proposes management objectives for their attainment; it is the precurser of Wildlife Management in Wilderness (1978) by the same authors.
KEYWORDS: Wildlife management, wilderness management.

192. Schoenfeld, C. A., and J. C. Hendee.
1978. Wildlife management in wilderness. 172 p. The Boxwood Press, Pacific Grove, Calif.

Addresses man-wildlife interactions in wilderness. Looks at the problems of wildlife management (largely the management of man) within the restrictions of the Wilderness Act. Contains many examples of man-wildlife interactions.
KEYWORDS: Wildlife management, wilderness.

193. Smith, O. A., Jr., and A. D. Geis.
1956. Comparative psychology in wildlife conservation. Am. Psychol. 11:183-187.

Suggests that comparative psychology might be used to alter the behavior of game animals so that they could avoid dangerous situations. This could allow the animals to survive longer and in turn provide better recreational opportunities for man. Proposes some psychology courses that would benefit researchers. Suggests that this aspect of wildlife management would open employment opportunities in the field of conservation.
KEYWORDS: Animal behavior, wildlife management.

194. Stokes, A. W., and D. F. Balph.
1965. The relation of animal behavior to wildlife management. Trans. North Am
Wildl. Nat. Resour. Conf. 30:401-410.

The authors feel that wildlife biologists should be educated in the field of anim behavior and apply behavioral concepts to management problems.
KEYWORDS: Animal behavior, wildlife management.

195. U.S. Department of Interior.
1977. A summary of the natural resources management plan, Yosemite National Park. U.S. Dep. Interior, 15 p. Washington, D.C.

Contains a management plan for wildlife and fisheries. Problems with man-black bear interactions have prompted the need to control artificial food sources.
KEYWORDS: Wildlife management, Yosemite National Park.

RECREATION MANAGEMENT

Social Science/Wildlife Management Relationships

196. Clark, R. N.
1974. Social science, social scientists, and wildlife management. *In* 38th Federal-Provincial Wildl. Conf. Trans. p. 103-107. Victoria, B. C.

Discusses the need for incorporating social science concepts and procedures into vildlife management programs to provide wildlife benefits to people. The problems involved include: misunderstandings due to technical language and specialized orienta-ion, inability to accept advice from another discipline, and lack of clearly defined bjectives.
KEYWORDS: Wildlife management.

97. Hendee, J. C., and D. R. Potter.
1971. Human behavior and wildlife management: needed research. Trans. North Am. Wildl. Nat. Resour. Conf. 36:383-396.

This paper is written from the consumptive viewpoint. It points out need for esearch to determine what kind of uses man wants to make of wildlife.
KEYWORDS: Human behavior, wildlife management.

98. Hendee, J. C., and C. A. Schoenfeld.
1973. Human dimensions in wildlife programs. Wildlife Management Inst. 193 p. Washington, D.C.

This report is concerned with the human behavior aspects of wildlife management. xamines outdoor and wildlife recreation experience, hunter satisfactions, antihunter ttitudes, and applying human dimensions to wildlife management.
KEYWORDS: Human behavior, wildlife management.

99. Lime, D. W.
1976. Wildlife is for non-hunters too. J. For. 74(9):600-604.

Suggests kinds of nonhunting wildlife experiences that could be offered to recrea-ionists. Because recreationists value seeing and hearing wildlife, forest managers hould offer opportunities for visitors to see and hear wildlife, and to see evidence f wildlife. Suggests talks, movies, nature walks, self-guiding trails, and nature nters.
KEYWORDS: Wildlife, recreation.

00. Lime, D. W., D. H. Anderson, and L. D. Mech.
1978. Guided expeditions to encounter wildlife: a plus for forest recreation users in Minnesota. For. Assoc. for Interpretive Naturalists, West. Interpreters Assoc. Workshop-Conference, April 5-7, 1978. Tucson, Ariz. 15 p.

"Two 1974 studies in the Superior National Forest of Minnesota demonstrate some sitive effects people gain from encountering wildlife. Participants in wolf howling faris and wildlife sign safaris enjoyed even indirect encounters with wildlife." ese techniques could be used for public information and managing use patterns.
KEYWORDS: Wildlife, recreation, education, recreation management.

Human Attitudes and Perceptions of Wildlife

(Also see reference numbers 88, 217, 231)

201. Bart, W. M.
1972. A hierarchy among attitudes towards animals. J. Environ. Educ. 3(4):4-

Notes that the behavior of men will determine if endanged wildlife species will survive or be exterminated. A ranking of human attitudes toward different animals wa obtained. Suggests educators work to change human attitudes toward animals in order protect rare and endangered species.
KEYWORDS: Wildlife, human attitudes.

202. Brown, R. J., B. L. Driver, and G. H. Stankey.
1976. Human behavioral science and recreation management. *In* 16th IUFRO Worl Congr., Div. 6, [Oslo, Norway, June 1976] Proc., p. 53-63. Int. Union For. Res. Organ., Vienna, Austria.

Suggests that understanding recreational preferences and human behavior can be useful in making recreational management decisions.
KEYWORDS: Recreation, human behavior, recreation management.

203. Bryan, R. B., and M. C. Jansson.
1973. Perception of wildlife hazard in national park use. *In* Human dimensio in wildlife programs. p. 129-142. J. C. Hendee and C. A. Schoenfeld., eds. Wildlife Manage. Inst. 193 p. Washington, D.C.

Increasing visitation and road networks have increased contact between tourists wildlife and the potential for accidents. Describes questionnaire survey of visitor perception of wildlife. Concludes that increasing urbanization reduces the accuracy the public's perception of wildlife and may indirectly have unfavorable results for wildlife.
KEYWORDS: Wildlife, danger, national parks.

204. Hendee, J. C., and R. J. Burdge.
1974. The substitutability concept: implications for recreation research and management. J. Leisure Res. 6:157-162.

Leisure activity substitutability is defined as the interchangeability of recrea- tion activities in satisfying the needs of the participants. In some cases, settings are of prime importance. In many other cases, the activity is more important than th place, and other activities or places could be substituted. This concept could be used to reduce disturbance of wildlife.
KEYWORDS: Recreation management.

205. Hendee, J. C., and G. H. Stankey.
1973. Biocentricity in wilderness management. Bioscience 23(9):535-538.

Presents a biocentric approach (i.e., maintenance of nearly natural energy flows within a wilderness ecosystem) to wilderness management. Unnatural changes in wilderness are often irreversible. A biocentric approach as opposed to an anthropocen- tric approach preserves options and facilitates a uniform and practical management policy.
KEYWORDS: Wilderness management.

206. Kellert, S. R.
1976a. Attitudes and characteristics of hunters and anti-hunters and related policy suggestions. Working pap. presented to Fish and Wildl. Serv., USDI, Nov. 4, 1976. 55 p.

Reports on a study of human attitudes and perceptions about wildlife, habitat, and unting. Examines basic differences in philosophical outlook and sociocultural back-rounds of hunters and anti-hunters for potential application to wildlife management ractices. Develops a typology of nine basic attitudes toward animals, and examines unters and anti-hunters in relation to these attitudes. Recommends better conservation ducation programs and a reorganization of governmental regulatory activities to nclude expanded concern and funding for nongame wildlife species.

KEYWORDS: Human attitudes.

07. Kellert, S. R.
1976b. Perception of animals in American society. Trans. North Am. Wildl. Nat. Resour. Conf. 41:533-545.

This paper provides a typology of American attitudes toward animals to better nderstand people's motivations for involvement in animal-related activities such as unting, pet ownership, birdwatching, etc. The distribution of these attitudes among ajor population groups (age, sex, education) and among major animal activity groups hunters, humanitarians, and wildlifers) is discussed. Sex and education were the ost important differentiators of attitudes toward animals.

KEYWORDS: Human attitudes, birdwatchers.

08. Kellert, S. R.
1977a. Americans and animals: perceptions and policy implications. Working pap. presented to Fish and Wildl. Serv., USDI. 37 p.

Deals with animal-related perceptions and activities of some major demographic roups in America. Attempts to provide practical orientation for management policies nvolving animal related issues such as endangered species, migratory bird protection, nimal damage control, trapping, etc.

KEYWORDS: Human attitudes.

09. Kellert, S. R.
1977b. Attitudes towards animals and characteristics of various animal activity groups other than hunters. Working pap. presented to Fish and Wildl. Serv., USDI. 35 p.

This paper focuses on attitudes and characteristics of a variety of nonhunting ctivity groups such as backpackers, birdwatchers, zoo enthusiasts, trappers, etc. olicy implications are suggested for each group according to the kinds of attitudes, ocial characteristics, and geographic distribution.

KEYWORDS: Human attitudes, backpackers, birdwatchers.

10. Mihalic, D. A.
1974. Visitor attitudes toward grizzly bears in Glacier National Park, Montana. M.S. thesis. Mich. State Univ., East Lansing. 131 p.

The author attempted to determine visitor attitudes toward grizzly bears and the fect of that attitude on potential behavior in hypothetical bear-encounter situations. found that visitor attitude toward bears was not related to potential visitor behavior.

KEYWORDS: Grizzly bear, human attitudes, Glacier National Park.

211. Stankey, G. H.
1976. Wilderness fire policy: an investigation of visitor knowledge and belie USDA For. Serv. Res. Pap. INT-180, 17 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

"Discusses attitudes and knowledge of wilderness visitors towards wilderness fir suppression policy. Although most users favored suppression, a substantial minority favored a more natural role for fire. A major finding was that as visitor knowledge about the role of fire increased, the likelihood of support for a more natural role f fire also grew. Important policy implications include educating and involving the public, making gradual changes in fire policy, and developing a communications progra aimed at different audiences." This technique could be applied to wildlife, substitu ing wildlife for fire.
KEYWORDS: Human attitudes.

212. Trefethen, J. B.
1975. An American crusade for wildlife. 409 p. Winchester Press and the Boo and Crockett Club.

Traces evolution of American attitudes toward wildlife from first settlers to present. Gives a historical account of extermination of wildlife. Contains numerous classic examples of the impact of man on wildlife.
KEYWORDS: Wildlife, human impact.

Modification of Human Behavior and Use Patterns to Reduce Impacts on Wildlife, Including Education

(Also see reference numbers 4, 23, 25, 34, 35, 38, 39, 68-70, 72, 75, 86, 93, 95, 97, 98, 102, 103, 105, 107-109, 111-113, 115, 121-123, 132, 133, 137, 151, 152, 167, 169, 177, 188, 200)

213. Bell, J. N.
1963. Wild animals are wild. Nat. Wildl. 1(5):34-36.

Suggests ways for national park visitors to avoid harmful interactions when encountering wildlife.
KEYWORDS: Wildlife, danger.

214. Curtis, S.
1974. How to track wildlife on skis. Backpacker 2(4):40-43, 79-80, 83.

Recommends techniques for approaching wildlife in winter for observation and photography. Warns of negative effects of disturbance on wintering wildlife. Cites snowmobile harassment of ungulates.
KEYWORDS: Wildlife, winter, skiers, photographers, ORV's.

215. Lime, D. W., D. H. Anderson, and L. D. Mech.
1978. Interpreting wildlife through guided expeditions. J. Interpret. 3(2)10-1

Guided expenditions were initiated in the Superior National Forest of Minnesota. People participating in wolf-howling safaris and wildlife-sign safaris had fun (in spite of only indirect encounters with wildlife) and at the same time learned about wildlife. This concept could be a useful method of public education about wildlife.
KEYWORDS: Wildlife, education.

16. Lochmiller, R. L.
1978. Birding! Virginia Wildlife 39(12):10-11.

Describes birdwatchers, their dedication, and equipment. Concludes with five rules f birdwatching etiquette: (1) Avoid use of tape-recorded territorial calls of rare birds hat are breeding; (2) observe nest from afar; (3) do not harass or handle eggs or young f rare or endangered birds; (4) respect property and wishes of private landowners; (5) void large groups, especially in critial habitat.

KEYWORDS: Birdwatchers, recreation management.

17. Trahan, R. G.
1977. Day-use limitation in national parks: visitor and park personnel attitudes toward day-use limitation systems for Rocky Mountain National Park. U.S. Dept. of the Interior, National Park Serv., Washington, D.C.

This paper reports on a study to determine attitudes, objectives, and perceptions f visitors and park personnel on day-use limitation systems in Rocky Mountain National ark. The objective was to develop a method of managing the increasing numbers of isitors. Although not immediately concerned with wildlife, methods used in this study ould be applied to regulation of visitors specifically to protect wildlife. Visitors avored noncoercive systems of limitation. Hikers considered environmental problems ood reasons for limiting day use.

KEYWORDS: Recreation management, Rocky Mountain National Park.

18. Wagar, J. A.
1964. The carrying capacity of wildlands for recreation. For. Sci. Monogr. 7:1-24.

This study analyzes carrying capacity in terms of (1) impact of recreational nvironment on people, (2) impact of people on the environment, (3) impact of people on eople, and (4) management procedures to modify these reciprocal impacts. Management onsiderations include zoning, engineering, interpretation, and persuasion. These anagement methods could be applied to reduce man's impacts on wildlife.

KEYWORDS: Recreation management.

19. Wagar, J. A.
1975. Recreational insights from Europe. J. For. 73(6):353-357.

Describes zoning in European parks and forests. Some interesting and original echniques are used to separate mass recreation from natural areas. Includes examples f subtle zoning techniques and "hard line" zoning. These techniques could be applied o reduce man-wildlife conflicts in North America.

KEYWORDS: Recreation management.

20. Wagar, J. A.
1977. Resolving user conflicts. *In* Wildland recreation. p. 135-144. [Feb. 28-Mar. 3, 1977, Banff Center, Univ. Alberta.]

Seeks methods to manage increasing numbers of recreationists by: (1) establishing system with zones that provide many options and protecting each option from people eeking values not intended for that option; (2) making the system visible so that eople can choose the options they want; (3) improving energy flows through public articipation in goal setting, interpretation to enrich visitor experience, and ncouraging desired behavior; and, (4) when all else fails, regulation and enforcement. oncepts could be applied to wildlife problems.

KEYWORDS: Recreation management.

221. Wagar, J. V. K.
1940. Certified outdoorsmen. Am. For. 46(11):490-492, 524-525.

Modern man with easy access and insufficient know-how is destructive of nature. Suggests an outdoor certification program and methods by which this might be accomplish This is a potential method of reaching people to educate them concerning wildlife-man interactions.
KEYWORDS: Recreation management, backcountry certification.

Bibliographies on Closely Related Subjects

(Also see reference numbers 31, 82, 87)

222. Bury, R. L., R. C. Wendling, and S. F. McCool.
1976. Off-road recreation vehicles, a research summary, 1969-1975. Texas Agric Exp. Stn., College Stn., Texas. Texas A&M Univ. System. 84 p.

Contains section on effects of ORV's on wildlife. Reviews major papers on effects of snowmobiles on large animals, medium-sized animals, small animals, and fish, and ORV effects on desert animals.
KEYWORDS: Desert animals, wildlife, winter, ORV's, bibliography.

223. Hieb, S. R., ed.
1976. Proceedings of the Elk-Logging Roads Symposium, Moscow, Idaho. For. Wild and Range Exp. Stn., Univ. Idaho, Moscow. 142 p.

Symposium on effects of logging and roads on elk in the Western States. Many papers include information on elk behavior and various man-elk interactions related to logging and roads. Some management suggestions that could be applied to backcountry situations.
KEYWORDS: Elk, logging, roads.

224. Leedy, D. L.
1975. Highway-wildlife relationships, vol. 1. A state-of-the-art report. Fed. Off. Res. and Develop., Rep. FHWA-RD-76-4, Dec. 1975. 193 p. Fed. Highw. Admin., Off. Res. and Develop., Washington, D.C.

Assesses highway-wildlife relationships and suggests research and management to protect and enhance fish, wildlife, and environmental quality.
KEYWORDS: Wildlife, highway.

225. Leedy, D. L., T. M. Franklin, and E. C. Hekimian.
1975. Volume 2, An annotated bibliography. Fed. Off. Res. Develop. Report No. FHWA-RD-76-4, Dec. 1975. 427 p. Fed. Highw. Admin. Off. Res. and Develop., Washington, D.C.

Bibliography with detailed annotations. Includes a number of articles applicable to man-wildlife interactions in the backcountry.
KEYWORDS: Wildlife, highway, bibliography.

226. Luckenbach, R. A., and R. B. Bury.
[In Press]. Off-road vehicle impact on desert vertebrates: A review. *In* The physical, biological, and social impacts of off-road vehicles on the California desert. K. Berry, ed. Spec. Publ., South. Calif. Acad. Sci.

Excellent review of the effects of ORV's on animal groups from fishes, to large mammals. Research recommendations and extensive bibliography.
KEYWORDS: Desert animals, ORV's, bibliography.

27. Neil, P. H., R. W. Hoffman, and R. B. Gill.
1975. Effects of harassment on wild animals-an annotated bibliography of selected references. Colo. Div. Wildl. Spec. Rep. 37, 21 p.

References and annotations on selected papers dealing with the effects on wild imals of ORV's, free-roaming pets (dogs and cats), urbanization, roads, wildlife abitat alterations, and hunting.
KEYWORDS: Wildlife, harassment, ORV's, dogs, bibliography.

28. Potter, D. R., K. R. Sharpe, and J. C. Hendee.
1973. Human behavior aspects of fish and wildlife conservation: an annotated bibliography. USDA For. Serv. Gen. Tech. Rep. PNW-4, 288 p. Portland, Oreg.

Bibliography of human behavior aspects of fish and wildlife conservation. Oriented oward hunting and fishing, but some references apply to backcountry recreation.
KEYWORDS: Wildlife, recreation, bibliography.

29. Speight, M. C. D.
1973. Outdoor recreation and its ecological effects: a bibliography and review. Discussion papers in Conservation No. 4. 50 p. Univ. College, London.

Contains section on impact of recreational activities on animals. Reference ource for European literature.
KEYWORDS: Wildlife, recreation, bibliography, Europe.

30. Wall, G., and C. Wright.
1977. The environmental impact of outdoor recreation. Dep. Geogr. Publ. Ser. 11, Univ. Waterloo, Ontario, Can., 69 p.

Contains section on wildlife that treats the direct effects of disturbance on ldlife as well as habitat changes caused by recreation. Reviews European, Canadian, nd American literature. Includes impacts of motorized vehicles.
KEYWORDS: Wildlife, human impacts, Europe, bibliography.

31. Walter, H.
1978. Impact of human activity on wildlife. *In* Sourcebook on the environment. p. 241-262. K. A. Hammond, G. Macinico, and W. B. Fairchild, eds. Univ. Chicago Press, Chicago.

An extensive literature review of impacts of human activities on wildlife, including plants. Reviews impacts resulting from human attitudes, pollution, development, eerhunting, pesticides, fire suppression, and controlled burning. Includes European nd African literature.
KEYWORDS: Bibliography, human impact, human attitudes.

32. Webb, R. H., and H. G. Wilshire.
1978. A bibliography on the effects of off-road vehicles on the environment. U.S. Geol. Surv. Open-file Rep. 78-149. 16 p.

This bibiography has a section on ORV impacts on desert wildlife.
KEYWORDS: ORV's, desert animals, bibliography.

APPENDIX

Author Index

A

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Common and Scientific Names

Birds

Gaviiformes	Loons
Gavia immer	Common loon
Anseriformes	Waterfowl
Olor buccinator	Trumpeter swan
Falconiformes	Vultures, Hawks and Falcons
Gymnogyps californianus	California condor
Buteogallus anthracinus	Black hawk
Aquila chrysaetos	Golden eagle
Haliaetus leucocephalus	Bald eagle
Pandion haliaetus	Osprey
Falco peregrinus	Peregrine falcon
Charadriiformes	Shorebirds, Gulls and Alcids
Larus argentatus	Herring gull
Sterna hirundo	Common tern
Columbriformes	Pigeons and Doves
Zenaiduria macroura	Mourning dove
Passeriformes	Perching Birds
Turdus migratorius	Robin
Sialia sialia	Eastern bluebird
Euphagus cyanocephalus	Brewer's blackbird
Molothrus ater	Brown-headed cowbird
Junco oregonus	Oregon junco

ammals[1]

Chiroptera	Bats
Myotis sodalis	Indiana or social myotis
Tadarida brasiliensis mexicana	Mexican free-tailed bat
Lagomorpha	Hares and Rabbits
Sylvilagus audubonii	Desert cottontail

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[1] Nomenclature according to J. K. Jones, Jr., D. C. Carter, and H. H. Genoways. 975. Revised checklist of North American mammals north of Mexico. Occas. Pap. No. 28, ne Museum, Texas Tech. Univ., 14 p.

Rodentia	Rodents
Eutamias quadriyittatus	Colorado chipmunk
Eutamias townsendii	Townsend's chipmunk
Ammospermophilus leucurus	White-tailed antelope squirrel (antelope ground squirrel)
Spermophilus variegatus	Rock squirrel
Dipodomys ordii	Ord's kangaroo rat
Peromyscus maniculatus	Deer mouse
Neotoma spp.	Woodrat
Microtus montanus	Montane vole
Cetacea	Cetaceans
Eschrichtius robustus	Gray whale
Megaptera novaeangliae	Hump-backed whale
Carnivora	Carnivores
Canis latrans	Coyote
Canis lupis	Gray wolf
Ursus americanus	Black bear
Ursus arctos	Grizzly bear
Ursus maritimus	Polar bear
Felis concolor	Mountain lion
Artiodactyla	Even-Toed Ungulates
Cervus elaphus	Wapiti or elk or red deer
Odocoileus hemionus	Mule deer
Odocoileus virginianus	White-tailed deer
Alces alces	Moose
Rangifer tarandus	Caribou
Antilocapra americana	Pronghorn
Oremnos americanus	Mountain goat
Ovis canadenis	Mountain sheep
Ovis dalli	Dall sheep

Ream, Catherine, H.
1980. Impact of backcountry recreationists on wildlife: an annotated bibliography. USDA For. Serv. Gen. Tech. Rep. INT-84, 62 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

An annotated bibliography and evaluation of the literature on the effects of backcountry recreationists on wildlife. Literature was taken from biological, managerial, sociological, and popular publications. Orientation includes descriptions of impacts and methods of reducing impacts of recreationists on wildlife.

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The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

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THE ROLE AND USE OF FIRE IN THE SEMIDESERT GRASS-SHRUB TYPE

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THE ROLE AND USE OF FIRE IN THE SEMIDESERT GRASS-SHRUB TYPE

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RESEARCH SUMMARY

Historical evidence indicates that fires were present in the semidesert grass-shrub type in southeastern Arizona, but there is less supportive evidence for southern New Mexico and southwestern Texas. The change from grass to brush during the past 80 years was due to a combination of factors related to the intensification of grazing. These factors include: reduction of grass fuel, increased rodent activity, increased erosion that helps cover and irrigate mesquite seed, increased seed dispersal by livestock, increased seed source as more trees came to maturity, and reduction of the competing stands of perennial grasses.

Except for black grama, most grasses in the semidesert grass-shrub type recover from fire in 1 to 3 years. Black grama may take 3 to 8 years to recover, for droughts slow the rate of recovery. If grazing, fire, and droughts are all suppressing black grama simultaneously, it may never fully recover. Drought alone can permanently damage black grama, for the severe drought of 1951 to 1956 on the Jornada Experiment Station, without grazing, reduced black grama on deep sandy and low hummocky sites so severely that it will never recover in our lifetime (Herbel and others 1972). Forbs are not very abundant, but most seem to be favored by fire.

During dry seasons that follow 1 or 2 years of above-average summer precipitation, fire can be used to control burroweed, cactus species, broom snakeweed, creosotebush, and young mesquite plants. False-mesquite, velvet-pod mimosa, Wright baccharis, and fourwing saltbush recover quickly after burning. Wheeler sotol and barrel cactus are severely harmed by fire.

Natural fire frequency was approximated to be 10 years for southeastern Arizona. In southern New Mexico and southwestern Texas, it was probably less than every 10 years, for there is no written record of fire in southern New Mexico (Buffington and Herbel 1965).

Although fire prescriptions have not been developed for the southern desert grasslands, some general guidelines are recommended where fine fuel exceeds 600 lb/acre (674 kg/ha). These *guidelines* should be treated as such and used in conjunction with the management implications. Generally, where there are medium or heavy infestations of brush, there is not enough fine fuel to carry a fire. Research needs are mentioned in the state-of-the-art section.

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INTRODUCTION

Grasslands in the semidesert grass-shrub type have gradually given way to higher and higher densities of shrubs during the past 75 years (fig. 1), but the mechanisms by which the invasion has taken place are not well understood (Buffington and Herbel 1965; Martin 1975). The historical role of fire is especially perplexing because fires that kill shrubs usually kill grasses too (Martin 1975). Buffington and Herbel (1965) were also skeptical about the role of fire in desert grasslands and did not consider fire as a factor in the maintenance of brush-free range in southern New Mexico. However, Thornber (1907, 1909), Griffiths (1910), Wooton (1916), Leopold (1924), and Humphrey (1958) were convinced that fire controlled shrubs in those portions of the semidesert grass-shrub type that had sufficient fine fuel. "That such fires burning over the mesas and foothills have not been uncommon in times past may be judged by the fact that in many places abundant remains of charred stumps of at least 10 years duration are frequently met with" (Thornber 1910). Wooton (1916) commented on fires severe enough to kill plants 10 to 12 ft (3.0 to 3.7 m) high.

Despite the skepticism about fire in controlling shrubs in desert grasslands, climate has not changed enough to account for the rapid increase of shrubs (Gardner 1951; Paulsen 1956; Humphrey 1958; Buffington and Herbel 1965). Moreover, once velvet mesquite (*Prosopis glandulosa* var. *velutina*) or honey mesquite (*P. glandulosa* var. *glandulosa*) seed trees were present, mesquite seedlings increased in Arizona and New Mexico whether pastures were protected or grazed (Griffiths 1910; Wooton 1916; Leopold 1924; Glendening 1952; Buffington and Herbel 1965). This leaves the distinct possibility that occasional fires, in combination with drought, competition, rodents, and lagomorphs played a significant role in controlling shrubs in the semidesert grass-shrub type (Griffiths 1910; Wooton 1916; Leopold 1924; Branscomb 1956; Humphrey 1958; Bock and others 1976), except on black grama uplands (Buffington and Herbel 1965).

DISTRIBUTION, CLIMATE, SOILS, AND VEGETATION

Distribution

Semidesert grass-shrub vegetation occurs in broad basins, slightly sloping drainages, and lower slopes of the southern Rocky Mountains in southeastern Arizona, southern New Mexico, and southwestern Texas (fig. 2) (Humphrey 1958; Martin 1975; Bunting 1978). The relatively flat terrain is interrupted by mountain ranges that rise abruptly to elevations of 8,239 to 10,713 ft (2 512 to 3 266 m) (Humphrey 1958; Martin 1975; Bunting 1978). Approximately 44 million acres (17 813 765 ha) occur in the United States, but the center of the semidesert grass-shrub type lies in Mexico (Clements 1920). Elevation of this vegetative type usually ranges from 3,000 to 4,500 ft (915 to 1 372 m) in Arizona and New Mexico (Martin and Cable 1974), but occurs as high as 5,707 ft (1 740 m) in southwestern Texas (Bunting 1978). Below the semidesert shrub-grassland lies the Chihuahuan desert and above it the vegetation gives way to chaparral, pinyon-juniper, oak woodland, or occasionally to grassland (Martin 1975).

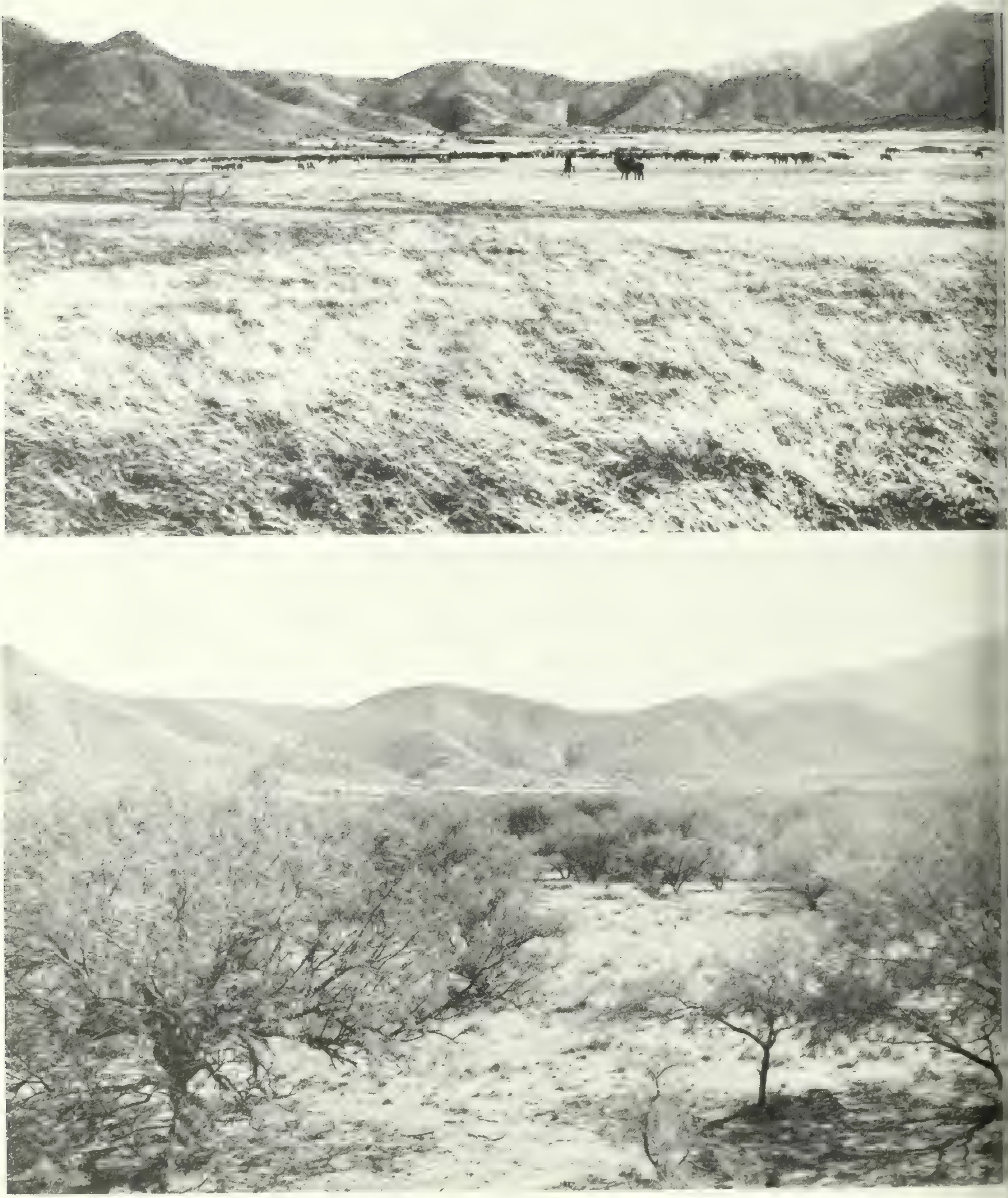
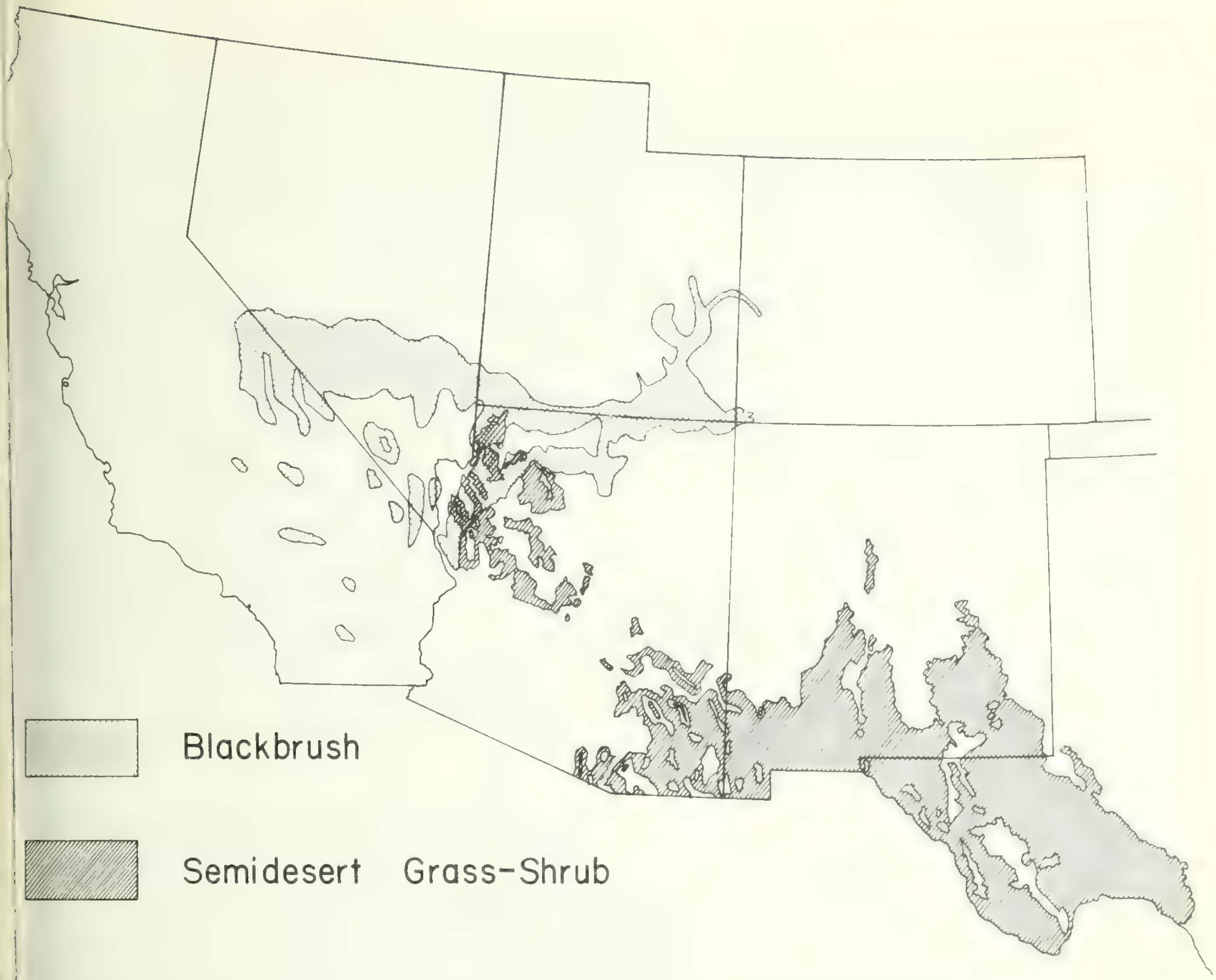


Figure 1.--A. Open grass-covered area on the Santa Rita Experimental Range in 1903. There are very few widely scattered velvet mesquite trees. B. Same area as 1A in 1941 with a well developed stand of velvet mesquite.



igure 2.--Distribution of semidesert grass-shrub vegetation (after Küchler 1964) and blackbrush vegetation (after Bowns and West 1976).

Climate

Average annual precipitation ranges from 8 inches (20 cm) at the western edge of ucson to 20 inches (51 cm) on the lower slopes of mountain ranges in southeastern rizona and southwestern Texas (Martin 1975). In south-central New Mexico, average nnual rainfall on the Jornada Experimental Range is 9.1 inches (23 cm). Throughout he semidesert grass-shrub region, over 50 percent of the annual rainfall occurs etween July 1 and September 30 (Hinckley 1944; Buffington and Herbel 1965; Cable 1972).

Soils

Soils vary widely from sandy or gravelly loams to clays in both the surface and ubsoil (Buffington and Herbel 1965; Cable 1972). They have developed primarily in lluvium from the adjacent igneous and limestone mountains, are characteristically mmature, light colored, and low in organic matter (Bunting 1978). Light precipitation nd high evaporation often result in an accumulation of salts in and below the soil in asins. Thus, concentrations of $CaCO_4.2H_2O$ (gypsum) and $CaCO_3$ (lime) occur in many oils throughout the region (Carter and Cory 1930).

Mesa and upland soils of the black grama community are compacted sands, shallow, and usually are 12 inches (30 cm) or less in depth. Frequently they are underlain by caliche (Nelson 1934; Martin 1975). Mixed grama (*Bouteloua* sp.) occurs on a wide variety of soils (Martin 1975), and mesquite grassland occurs mainly on sandy soils (Buffington and Herbel 1965). Creosotebush (*Larrea tridentata*) grows best on limestone-derived alluvial fans (Fosberg 1940) and is absent on soils having gypsum in the profi (Waterfall 1946; Buffington and Herbel 1965). Tarbush (*Flourensia cernua*) also grows on limestone-derived soils but predominates on deep well-drained soils (Buffington and Herbel 1965). Clay soils and fine silts, generally in swales and basins, are deep to moderately deep, poorly drained, calcareous, and contain appreciable quantities of readily soluble salts. They usually support tobosagrass (*Hilaria mutica*) and/or one o the sacaton species (*Sporobolus airoides, S. wrightii*) (Buffington and Herbel 1965; Bo and Bock 1978).

Vegetation

Major vegetational communities include the black grama uplands (fig. 3) of New Mexico and west Texas, the flood plains of tobosagrass (fig. 4), sacaton (*Sporobolus wrightii*) (fig. 5), or alkali sacaton (*S. airoides*) that occur along water courses, mixed grama (*B. gracilis, B. hirsuta, B. chondrosioides*) grasslands, mesquite-infested grasslands, the widespread creosotebush stands, and the tarbush, whitethorn (*Acacia constricta*), and creosotebush areas of adjoining and included portions of the Chihuahu desert (Martin 1975).

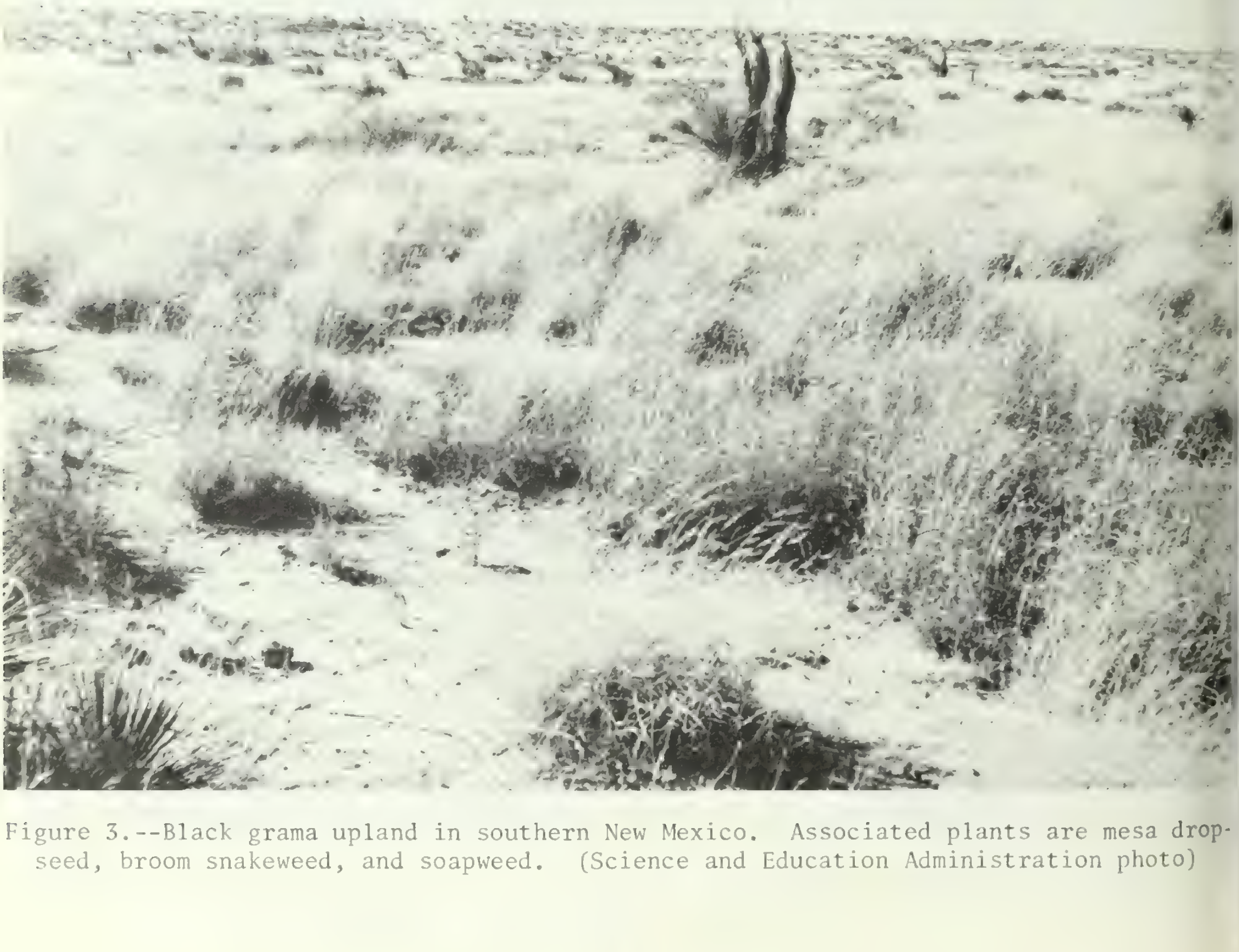


Figure 3.--Black grama upland in southern New Mexico. Associated plants are mesa dropseed, broom snakeweed, and soapweed. (Science and Education Administration photo)

gure 4.--Tobosagrass flood plain that is typical of southern Arizona, New Mexico, and southwestern Texas. Soils are usually nonsaline. (Science and Education Administration photo)

Igure 5.--Sacaton grassland in southeastern Arizona. It is typical of saline flood plains.

Black grama and tobosagrass are the most common grasses in the semidesert shrub-grassland (Paulsen and Ares 1962). A rothrock grama (*Bouteloua rothrockii*) community is abundant in Arizona and a curly mesquite (*Hilaria belangeri*) community is scattered throughout the desert grassland on well-drained clay soils (Shantz and Zon 1924; Humphrey 1953). Other species in Arizona include annual needle grama (*B. aristidoides*) annual sixweeks threeawn (*Artistida adscenionis*), tall threeawns (*A. hamulosa* and *A. ternipes*), Santa Rita threeawn (*A. glabrata*), bush muhly (*Muhlenbergia porteri*), Arizona cottontop (*Trichachne californica*), tanglehead (*Heteropogon contortus*), hairy grama (*B. hirsuta*), sideoats grama (*B. curtipendula*), and plains lovegrass (*Eragrostis intermedia*). Principal plant species in New Mexico on well-drained sites include black grama, mesa dropseed (*Sporobolus flexuosus*), threeawns (*Aristida* sp.), and fluffgrass (*Erioneuron pulchellum*). Low-lying areas contain tobosagrass and burrograss (*Scleropog brevifolius*) (Buffington and Herbel 1965). In Texas, blue grama (*B. gracilis*), sideoat grama (*B. curtipendula*), vine-mesquite (*Panicum obtusum*) warnock grama (*B. warnockii*), bush muhly, dropseed (*Sporobolus* sp.), hairy tridens (*Erioneuron pilosum*), and Wooton threeawn (*Aristida pansa*) may be added to the predominant stands of black grama, alkali sacaton, and tobosagrass (Bunting 1978). Lehmann lovegrass (*Eragrostis lehmanni*) and Boer lovegrass (*Eragrostis chloromelas*) are the most commonly seeded grasses in the semidesert type (Martin 1975). Forbs are not very prevalent (Bunting 1978).

Common shrubs include mesquite, creosotebush, tarbush, fourwing saltbush (*Atriplex canescens*), soapweed (*Yucca elata*), and broom snakeweed (*Xanthocephalum sarothrae*) (Buffington and Herbel 1965; Martin 1975). Burroweed (*Aplopappus tenuisectus*) is prevalent in southern Arizona and southwestern New Mexico and some acacias (*Acacia* sp.) may be found throughout the entire region (Martin 1975). Cane cholla (*Opuntia spinosior*), jumping cholla (*O. fulgida*), and Englemann's pricklypear (*O. engelmannii*) are common cactus species (Cable 1972).

Herbage Yields

Herbage yields are quite variable. Martin (1966) found that herbage yields ranged from 5 to 250 lb/acre (5.6 to 281 kg/ha) on a mesquite-infested range that received 10 to 12 inches (25 to 30 cm) of precipitation annually. In an area of higher annual rainfall (16 inches [41 cm]), yields ranged from 300 to 1,200 lb/acre (337 to 1 348 kg/ha) under a scattered stand of mesquite. In another case on the Santa Rita Experimental Range where precipitation averaged from 7.4 inches (19 cm) in the driest pasture to 10.8 inches (27 cm) in the wettest pasture, yields ranged from 17 to 498 lb/acre (19 to 560 kg/ha) (Martin 1975). On the Jornada Experimental Range where precipitation averages 9.1 inches (23 cm) annually, Herbel (cited by Martin 1975) reported yields as high as 800 lb/acre (899 kg/ha) on black grama upland sites and 3,500 lb/acre (3 933 kg/ha) on tobosa-alkali sacaton flood plains.

POSSIBLE ROLE OF FIRE IN SEMIDESERT GRASS-SHRUB TYPE

The environmental and biological factors that may have limited the invasion of shrubs into desert grasslands before the arrival of European man in North America have to be looked at simultaneously to evaluate the possible role of fire. Vigorous perennia grasses compete strongly with mesquite seedlings (Martin 1975; Wright and others 1976). Experiments on the Santa Rita Experimental Range showed that 16 times as many mesquite seedlings were established on bare areas as in vigorous stands of perennial grasses (Glendening and Paulsen 1955). Wright and others (1976) found similar results in west Texas with no survivors in tobosagrass. Moreover, once established, growth of young mesquite plants is severely restricted in good stands of grass, for the author observed a mesquite plant 12 inches (30 cm) tall in black grama grass that had been planted 18 years before the date that the author saw it on the Santa Rita Experimental Station. Thus, competition is a key factor in keeping shrubs suppressed. Moreover, frequent droughts in the semidesert grass-shrub type (Nelson 1934) were just as hard on young mesquite plants as they were on the grasses (Bogusch 1952).

Droughts can have devastating effects on black grama (*Bouteloua eriopoda*), the most prevalent grass species in the semidesert grassland (Cottle 1931; Nelson 1934). However, black grama can recover quickly following protection and a couple of years of less-than-average to above-average precipitation (Cottle 1931; Nelson 1934; Cable 1975). In 2 years yield increased from 13 to 131 g/m^2 in southwestern Texas (Cottle 1931) and area of sets increased from 3.0 to 78.5 cm/m^2 in southeastern Arizona (Nelson 1934). Regrowth is usually slow the first year of rest but accelerates the second year (Cottle 1931; Nelson 1934). Therefore, when livestock was not a factor, a very susceptible plant such as black grama could have quickly reestablished itself with new stoloniferous plants and have been competitive with shrubs, if it had good vigor at the time of the catastrophy and was followed by average or better than average precipitation (Cottle 1931; Nelson 1934; Cable 1975). During the severe drought of 1951 to 1956, however, nearly all of the black grama on deep sandy and low hummocky sites was lost in an ungrazed exclosure and will not recover in our lifetime under complete protection (Herbel and others 1972). On shallow soils that were underlain by caliche, black grama was much more resistant to the severe drought.

Mesquite seedlings are most prevalent following warm summers and good fall rains (Wright and others 1976). Because grassland fires usually occurred during dry seasons that followed 1 or 2 years of average to above-average precipitation (Wright and Bailey, 1980), a high percentage of young mesquite plants could easily have been killed by fire (Glendening and Paulsen 1955; Wright and others 1976). The few surviving black grama plants (Reynolds and Bohning 1956) on black grama ranges might have recovered quickly, if ungrazed, because they received good summer rains the year before the fire (Cottle 1931; Cable 1975). However, findings by Reynolds and Bohning (1956), where moderate grazing was confounded with fire effects, leave one to doubt whether grazing can be permitted after a burn until black grama is completely recovered. Intervening droughts can lengthen the recovery period for several years (Nelson 1934; Reynolds and Bohning 1956).

For those areas that escaped fire, competition from healthy grass would reduce the number of mesquite plants 94 percent (Martin 1975). Those that survived would be fed on by jackrabbits (*Lepus alleni* and *L. californicus*) (Vorhies and Taylor 1933) and wood rats (*Neotoma* sp.) (Wright and Bailey 1980), especially during dry seasons o meet metabolic moisture needs. In southeastern Arizona velvet mesquite constituted 6 to 56 percent of all food consumed by jackrabbits (Vorhies and Taylor 1933). In well-preserved black grama grasslands, there are relatively small numbers of rodents and lagomorphs (Buffington and Herbel 1965). Thus, competition from grass and feeding y jackrabbits and wood rats appears to have, historically, been major factors that ontrolled the density and vigor of mesquite in southern desert grasslands.

Frequent droughts, insects, and diseases would also have taken their toll Bogusch 1952; Glendening and Paulsen 1955; Wright and Bailey 1980). Velvet mesquite seedlings rarely survived the first spring drought on well-grassed sites (Glendening and aulsen 1955). Those areas that escaped fire for 10 to 20 years could easily have ept young mesquite suppressed (via biotic and nonbiotic factors) to less than 0.5 inch 1.3 cm) in diameter. A fire at this time would kill 52 percent of such trees (Glendening nd Paulsen 1955) and probably have kept most of them in a nonseed producing state Humphrey 1958; Martin 1975). Thus, several factors interacting together with the help f fire and no grazing by domestic livestock could have kept shrubs, particularly esquite, out of the semidesert grasslands. Even black grama could have theoretically olerated occasional fires, when grazing was not a factor.

Overgrazing in Arizona, as practiced by forest administrators in the early 1900's to reduce fire hazard and promote the growth of trees (Leopold 1924), helped to prevent fires and let brush encroach upon the grassland (Griffiths 1910). Overgrazing on open range in desert grasslands, particularly during droughts, had a similar effect (Chew nd Chew 1965). Griffiths (1910) and Leopold (1924) concluded that before 1880, the outhern desert grasslands produced more grass and that fires occurred at approximately

10-year intervals. Initially, fire harmed the grasses, but 10 years was plenty of time for a lusty growth of grass to come back and accumulate the fuel for another fire (Leopold 1924). The poor seed source, slow establishment, and slow growth rate of shrubs and mesquite trees would have permitted a fire every 10 years to control the shrubs and mesquite trees (Griffiths 1910). The key seems to be to burn at frequent enough intervals to prevent the production of seed by the shrubs (Humphrey 1958; Chew and Chew 1965; Martin 1975). No seeds are borne by creosotebush (*Larrea tridentata*) younger than 13 years and significant numbers of fruits appear only after 18 to 20 years of growth (Chew and Chew 1965). With competition from biotic and nonbiotic factors, mesquite could also take this long to have seed (Humphrey 1958; Martin 1975). This reasoning, however, does not seem to apply for southern New Mexico because there is no historical evidence of fire (Buffington and Herbel 1965).

Today, grazing by domestic livestock is the biggest hindrance to the potential use of fire in semidesert grass-shrub vegetation, especially black grama ranges. Grazing has reduced fine fuel for fires and allowed shrubs to invade (Chew and Chew 1965; Martin 1975). Mesquite trees have become well established on former black grama ranges and have further reduced the chance for a site to produce enough fine fuel to carry a fire (Martin 1975). Fire might be used to prevent reinvasion (Martin 1975). In most cases, however, a major reclamation program, involving brush control and improved grazing systems, would be required to reclaim semidesert grass-shrub ranges to grass before fire could be introduced into a management program (Martin 1975; Wright and others 1976).

EFFECTS OF FIRE ON VEGETATION

Grasses

Following a 15-year burning study on the Santa Rita Experimental Range, Cable (1967) concluded that fire had no lasting effects, beneficial or detrimental on perennial grass cover. Generally, the detrimental effects of fire on most of the perennial grasses only lasted 1 to 2 years. Annual grasses (predominantly needle grama and six-weeks threeawn) due to the reduction in burroweed, doubled their yields during wet year (average or above-average precipitation), but remained the same as the control during dry years (below-average precipitation). Humphrey (1949) reported similar results about the response of annual grasses to fire.

Rothrock grama tolerates fire well unless burned during dry years. Reynolds and Bohning (1956) and Cable (1967) found that burning during a dry year caused a 30 percent reduction in rothrock grama. However, it had fully recovered by the end of the second growing season. In an earlier study, Humphrey (1949) found that numbers of rothrock grama plants were more abundant on two different burns near the Santa Rita Experimental Range than on controls 2 years after the burns.

Black grama is harmed most seriously of all the southern desert grasses and is very slow to recover. Following a hot June fire, Cable (1965) found that 90 percent of the black grama plants died. Even during a wet year, black grama only recovered 23 percent of its preburn basal area after the first growing season (Reynolds and Bohnin (1956). Following two subsequent drought years and moderate grazing, basal cover of black grama had increased to 33 percent. However, basal area of black grama dropped to 22 percent of the preburn basal area at the end of the fourth year when precipitation was above average. These data indicate that droughts following fire will lengthen the recovery period for black grama (Nelson 1934; Reynolds and Bohning 1956), and if compounded with moderate grazing, black grama will never recover to its preburn basal area (Canfield 1939).

Canfield (1939) found that moderate grazing (simulated by clipping plants to a stubble height of 5 cm) in combination with droughts, regardless of frequency or season of harvesting, reduced the yield of black grama to zero. Moderate grazing entirely outweighed the beneficial effects of above-average rainfall. The result was deterioration of black grama sites through excessive wind and water erosion. Thus, if black grama ranges are burned, they should be completely rested until after two consecutive years of above-average summer precipitation (Nelson 1934; Cable 1975). Then, if grazing is resumed, it should be light.

Rooting of stolons of black grama is the primary method of reproduction. Once these stolons are destroyed, forage is lost and the sand mulch is swept away by winter and spring winds (Herbel and others 1972) unless other grasses can be established on the site. In many cases, other forage does not become established.

Further north near Flagstaff, Arizona, where the precipitation is higher than southern New Mexico, Jameson (1962) noticed only a 25 percent reduction in black grama by prescribed fires. Even hot summer fires did not result in excessive damage. I have observed similar effects in a 15-inch (38-cm) rainfall area in southeastern New Mexico.

Santa Rita threeawn is favored by fire during wet or dry years, but tall threeawns are generally reduced 30 to 50 percent of their original basal cover (Humphrey 1949; Reynolds and Bohning 1956; Cable 1967). During the first growing season after burning, a dry year, Reynolds and Bohning (1956) found that the density of Santa Rita threeawn had increased 34 percent over the control. Following another dry year at the end of the second growing season, the density had doubled. And after the third growing season, a wet year, the density of Santa Rita threeawn had increased 350 percent. Such dramatic increases were not reported by Cable (1967) but it did increase. The reason that Santa Rita threeawn is more tolerant of fire than other threeawns has been explained by Cable (1967). Santa Rita threeawn generally grows in open areas between burroweed plants, whereas the other threeawns generally grow within the burroweed crowns. Thus, the tall threeawns are subjected to more heat and are easily harmed by fire, whereas many Santa Rita threeawn plants are not burned. Generally, threeawn species should be easily harmed by fire because their root-shoot region is close to the soil surface.

Arizona cottontop and tanglehead are mildly harmed by fire during dry years but recover quickly during wet years (Reynolds and Bohning 1956; Cable 1967). Neither of these species shows a gain in production following burning. However, in the southern mixed prairie where the average rainfall is twice as high as in the southern desert grasslands, Arizona cottontop responds very favorably to fire during wet years (Wright 1974). Based on limited data, bush muhly appears to be seriously harmed by fire (Humphrey 1949).

Tobosagrass, a dominant of the southern desert grasslands in southern New Mexico and southeastern Arizona, is severely harmed by burning during dry years (produces only 30 to 60 percent as much as the control), but will recover fully by the end of the third growing season if normal precipitation follows the dry year (Dwyer 1972). In the southern mixed prairie, yield of this species increases twofold to threefold if the soil is moist at the time of burning (Wright 1969; 1972). These differences in response to fire between the two vegetative types can be attributed to differences in precipitation.

Alkali sacaton and sacaton communities, which are similar in density, coarseness, and structure to tobosagrass, were probably burned more frequently in their natural state than tobosagrass communities (Humphrey 1962). Records of fire occurrence are extremely rare. Mesquite and acacia have taken over many sacaton communities. Contributing factors have been overgrazing and channel cutting, which eliminates periodic flooding and lowers the water table. Sacaton grasslands require 2 years to fully regain plant cover and 54 percent of original height (Bock and Bock 1978).

In this community vine-mesquite was significantly more abundant on a winter burned ar
than on an unburned area (Bock and Bock 1978).

On the northern boundary of the semidesert grass-shrub type, galleta (*Hilaria jamesii*) is slightly harmed by fire (Jameson 1962; Dwyer and Pieper 1967). Following winter burns with adequate soil moisture, galleta yielded 75 percent as much forage th first growing season after burning as the unburned control.

Wolf plants of Lehmann lovegrass, an introduced species, are severely reduced by hot wildfires in June, but seedlings quickly reestablish on the burned areas (Cable 1965). A burn that was followed by unusually favorable moisture for plant growth reduced a stand of Lehmann lovegrass about one-third (Humphrey and Everson 1951). Seedlings were abundant, however, and the reduction in forage yield was only temporary. Following a February burn, Pase (1971) found that lovegrass in a chaparral community was essentially unaffected by burning. Because this species of lovegrass is a bunchgrass, damage by fire would be related to intensity of the fire, amount of dead fuel i plant crowns, soil moisture, and precipitation that followed the burn.

Forbs

Forbs are generally not mentioned in the literature for semidesert grass-shrub communities, but Bock and Bock (1978) reported that forbs which were more common in sacaton communities after winter or summer burning included *Amaranthus, Ipomaea, Biden Convolvulus, Solidago, Portulaca, Chenopodium,* and *Ambrosia*.

Cacti

Cactus species are relatively susceptible to fire. Using data from three studies-Humphrey (1949), Reynolds and Bohning (1956), and Cable (1967)--average kills two grow seasons after a burn were jumping cholla, 50 percent; cane cholla, 45 percent; prickly 30 percent; barrel cactus (*Echinocactus wislizenii*), 65 percent. These mortalities usually included the interactive effects between fire, insects, drought, and grazing b rodents, lagomorphs, and domestic animals. For example, when the spines of barrel cac are burned off, cattle eat them readily (Reynolds and Bohning 1956).

Cane cholla and pricklypear do not recover from the effect of initial burns for at least 13 years after a burn (Cable 1967). However, jumping cholla increased 17 per 13 years after a burn. Reburns that were 3 years apart did not increase the mortality cactus species (Cable 1967). The reason given was that the first burn removed the accumulated weeds and litter from the base of cactus plants.

A study by Glendening (1952) also supports the need for fire to control cactus species. His 17-year study showed that cane cholla, pricklypear, and barrel cactus increased under protection and under moderate grazing. Jumping cholla was the only species that decreased under protection. However, jumping cholla has a life span of about 40 years and may go through rapid die-off cycles due to population buildups of bacillus (*Edwinea carnegieana*) (Tschirley and Wagle 1964; Martin and Turner 1977). Die-offs of 25 to 35 percent also occur in the other cactus species from time to time (Humphrey and Everson 1951). To date, there is no evidence to support the common belief that reduced grass competition, resulting from grazing, has caused cactus speci to flourish. More likely, lack of fire has caused them to flourish, as the evidence seems to suggest.

Shrubs

Griffiths (1910) and Wooton (1916) believed that fires almost entirely prevented the establishment of undesirable shrubs in the southern desert. Griffiths stated that because of the slow growth of shrubs, he believed they could be controlled by fires that occurred only once in 10 years. Wooton (1916) working in the same area (Santa Rita Experimental Range, Arizona) saw occasional fires that were hot enough to kill mesquite trees 10 to 12 ft (3.0 to 3.7 m) high. In his opinion, fire had been the only restricting influence on the spread of trees and shrubs. Although grasses, with the possible exception of black grama, recovered quickly from such burning, shrubs were usually just reappearing by the time another fire occurred. Regrowth from small mesquites that are merely top-killed can be rapid, however.

One of the most prevalent shrub-tree species in the Southwest is velvet mesquite. This species is moderately affected by fire, depending on the size of mesquite and amount of fine fuel available for burning (Cable 1961, 1965, 1967; White 1969). Following a June 28, 1963, wildfire, Cable (1965) reported a 21 percent kill of mesquite less than 2 inches (5 cm) in diameter and a 10 percent kill of trees larger than 2 inches (5 cm) in diameter. Using artificial fuels for controlled fires, Glendening and Paulsen (1955) obtained a 52 percent kill on young mesquites having basal stem diameters of 0.5 inches (1.3 cm) or less. Only 8 to 18 percent of the larger trees were killed by fire. Reynolds and Bohning (1956) killed 9 percent of the mesquite trees by using a prescribed burn on June 30, 1952. In a wildfire near Sasabe, Arizona, White (1969) reported a 20 percent kill of mesquite trees in moderate and severe burns.

Occasionally, fire may be more damaging to mesquite than is normally expected. Humphrey (1949) has reported mesquite kills of 50 percent on the Beach Ranch Study and 75 percent on the Sierrita Mountain Study. After 15 years, Humphrey revisited these same areas and still found mesquite drastically reduced. High kills such as these reported by Humphrey are rare. Part of this variation in mesquite kills, however, may be due to the amount of fuel available. On areas having 4,500 lb/acre (5 056 kg/ha) of fine fuel, fire killed 25 percent of the mesquites, but on areas having 2,200 lb/acre (2 472 kg/ha) of fine fuel, only 8 percent of the mesquites was killed (Cable 1965). Another source of variation is the general vigor of the plants. Mesquite plants with low vigor, growing on dense rocky subsoils, do not have the recovery potential that more vigorous trees do. Another factor may be the degree to which erosion has removed soil around the base of the tree thereby exposing the bud zone to heat. Lastly, summer burns are more damaging to mesquite than winter burns (Glendening and Paulsen 1955; Blydenstein 1957).

In addition to the mortality of plants, burning seems to inhibit the establishment of mesquite seedlings. Mesquite numbers on an unburned area increased from 16 to 52/acre (40 to 128/ha) within a 13-year period while they only increased from 24 to 25/acre (59 to 62/ha) on a burned area (Cable 1967). Reduced yield of mesquite seed on trees that were partially top-killed may be one reason for such an effect. The reduction in numbers of Merriam kangaroo rats (*Dipodomys merriamai*), resulting from the loss of cactus and other shrubs that formerly sheltered the rats, would also reduce the amount of seed cached on a burned area. Lastly, jackrabbits eat young mesquite plants (Vorhies and Taylor 1933), and the mortality of mesquite seedlings is higher on areas grazed by cattle and jackrabbits than in cattle-jackrabbit exclosures (Glendening 1952).

Generally speaking, velvet mesquite in southeastern Arizona is more susceptible to fire than honey mesquite, which grows in New Mexico and Texas. Two successive fires are necessary to kill 27 percent of the large honey mesquite trees on upland sites in the Rolling Plains of Texas, but trees are rarely killed with successive fires on bottomland sites (Wright and others 1976). Seedlings of honey mesquite are easy to kill with moderate fires until they reach 1.5 years of age, severely harmed at 2.5 years of age, and very tolerant of intense fires after 3.5 years of age (Wright and others 1976). At these young ages, velvet mesquite might be slightly more tolerant of fire based on data by Cable (1961) but his seedlings had been transplanted when 3 or 4 weeks old. On the High Plains (shortgrass prairie) of Texas, where mesquite was not reported by early scouts, honey mesquite is very tolerant to fire. We have observed no mortalit indicating that the plants have evolved in a fire environment and were kept suppressed by fire, droughts, competition, rodents, and lagomorphs (Wright and other 1976).

Other shrubs, only moderately affected by fire, are false-mesquite (*Calliandra eriophylla*) and velvet-pod mimosa (*Mimosa dysocarpa*). Very few of these plants (2-10 percent) died on severe burns and no plants died on light and moderate burns (White 1969). Reynolds and Bohning (1956) found that false-mesquite recovered within 2 years after burning and had almost doubled its crown density compared to unburned areas by the third year after burning.

Soapweed can be adversely affected by fire. Humphrey (1949) reported a 25 percent kill following a wildfire on Sierrita Mountain. In general, however, most *Yucca* species are tolerant of fires and appear to hold their position in various plant commuities despite fire.

Ocotillo (*Fouquieria splendens*) and Wheeler sotol (*Dasylirion wheeleri*) are severe reduced by fire (White 1969). In a June 1963 wildfire many plants of ocotillo died--67 percent in severe burns, 40 percent in moderate burns, and 50 percent in light burns Only 3 percent of the Wheeler sotol plants survived severe burns, but all survived in moderate and light burns.

Larchleaf goldenweed (*Aplopappus laricifolius*) is also easily killed by fire (White 1969). Severely damaged plants were completely killed and did not sprout by the end of the second growing season. Only 10 percent of the moderately damaged plants survived following fire. About 90 percent of the lightly damaged plants survived in the first growing season, but the number of survivors declined to 80 percent in the second growing season.

Paloverde (*Cercidium floridum*), broom snakeweed, and burroweed are three more species that can be severely damaged by fire. Humphrey (1949) reported a 90 percent mortality of paloverde on the Sierrita Mountain Study. Wooton (1916) observed that broom snakeweed was easily killed by fire. A later study showed that mortalities of broom snakeweed and burroweed following a July control burn were 95 percent or higher (Humphrey and Everson 1951). Cable (1967) and Reynolds and Bohning (1956) have also reported 95 to 100 percent kills for burroweed, when burned in June. One study on burroweed in which burning was done at all seasons of the year showed burning to be reasonably effective from mid-April to mid-September, but most effective about June 1 (Tschirley and Martin 1961).

After 6 years, Cable (1967) found that burroweed was only 25 to 30 percent of preburn density on a June burn (fig. 6), although it fluctuated upward during wet years and downward during dry years. After 4 years, burroweed exceeded preburn densities (fig. 6). However, in another study Humphrey (1949) found that burroweed failed to reinvade after 15 years following a wildfire. The most striking effect of June burns in southern desert grasslands is the elimination of burroweed, at least temporarily, and the increase in annual grasses during wet years (Cable 1967).

Thornber (1907) noted that fire was effective in killing catclaw (*Acacia greggii*), creosotebush, Mormon tea (*Ephedra trifurca*), and graythorn (*Condalia lycioides*). Except for creosotebush, however, no research studies document the extent to which these species are affected by fire. Creosotebush (fig. 7) can resprout after burning, but intense fires, particularly during June, will cause 100 percent mortality (White 1968; White and Ehrenreich 1968).

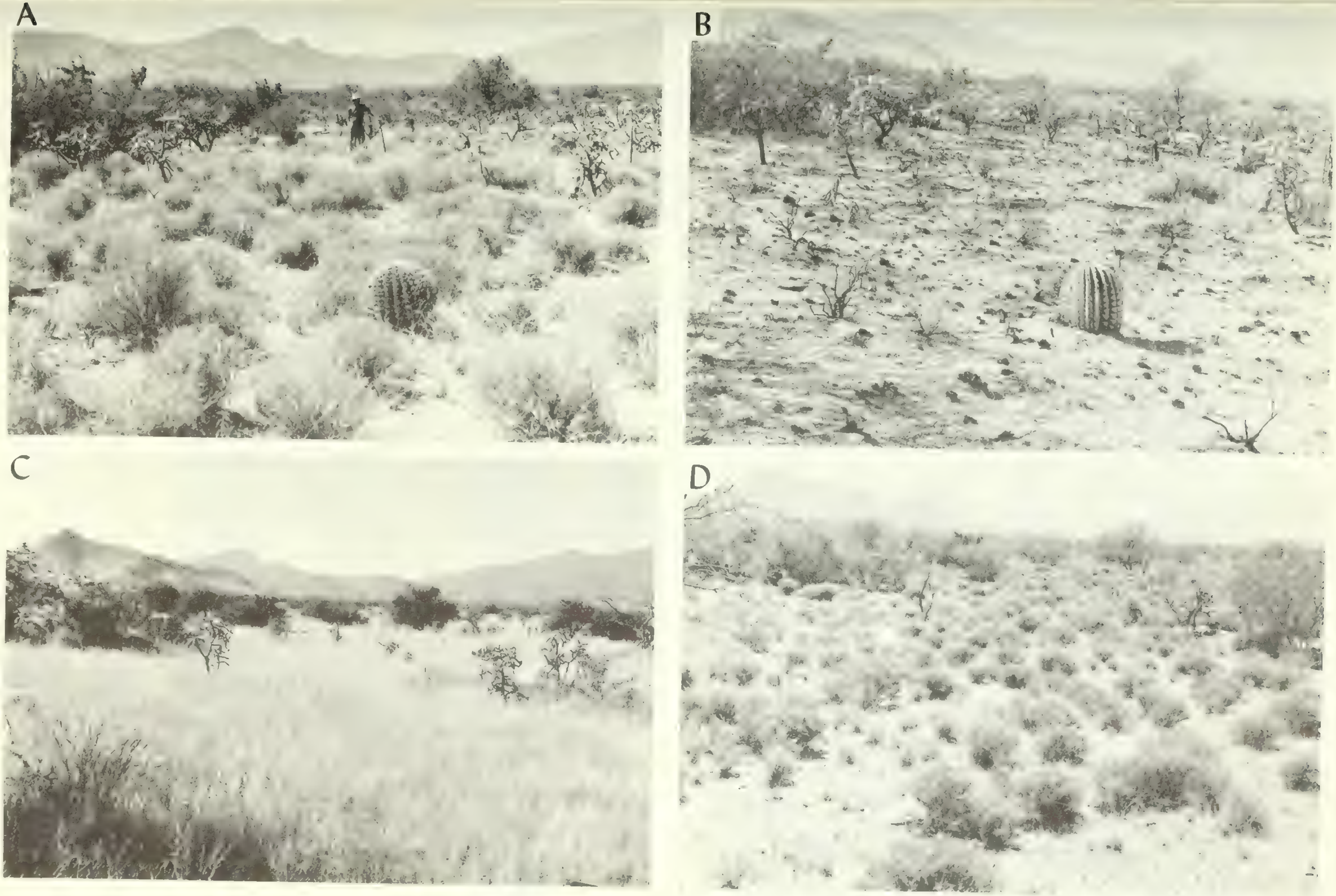


Figure 6.--A. A stand of 1,445 burroweeds per acre on the Santa Rita Experimental Range in June 1952. B. Same as 6A, July 1952, 8 days after burning. Fire killed 94 percent of burroweeds. C. Same as 6A, September 1958. The area is dominated by native perennial grasses. D. Same as 6A, September 1966, 14 years after burning. This sit has been reinvaded by burroweed, 10,433 plants per acre.

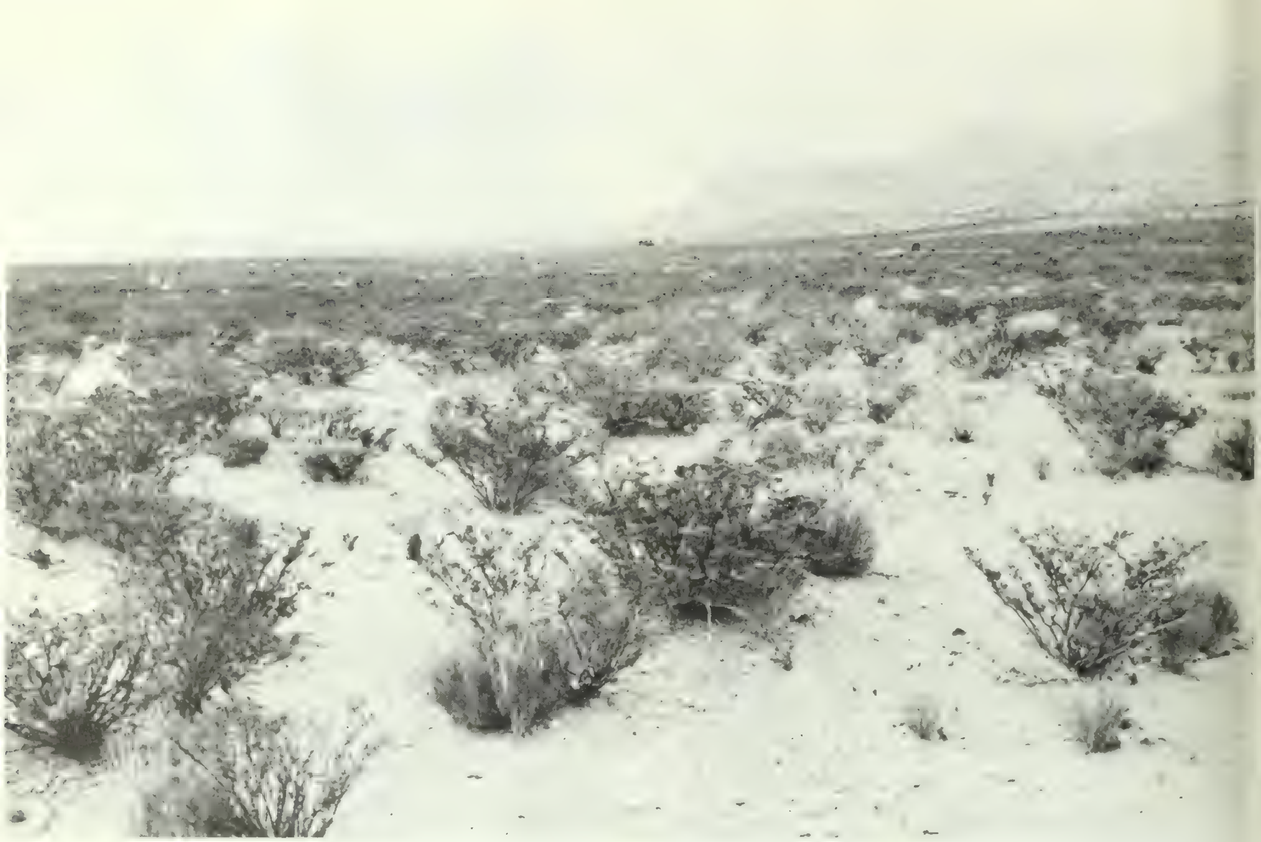


Figure 7.--Creosotebush is a widespread plant community in the semidesert zone and has very little herbaceous vegetation. However, it is susceptible to fire in June, indicating that wildfires could have easily kept it from invading grasslands in the past.

Algerita (*Berberis trifoliata*), fourwing saltbush, winterfat (*Eurotia lanata*), and skunkbush sumac (*Rhus trilobata*) resprout vigorously after fire (Dwyer and Pieper 1967). Wright baccharis (*Baccharis wrightii*), a highly palatable shrub, also resprouts vigorously and appears to be unaffected by fire (Humphrey 1949).

Desert blackbrush (*Coleogyne ramosissima*) (fig. 8), a nonsprouter in northern Arizona and southern Nevada and Utah (a transitional zone of vegetation between the salt desert shrub and the semidesert grass-shrub types), is very susceptible to fire and is slow to reinvade after fires in southern Nevada and Utah (Jenson and others 1960; Beatley 1966). Plant communities that succeed blackbrush are highly variable (Bowns and West 1976). Bowns and West found that some plant communities will return to a mixture of shrubs such as turpentine bush (*Thamnosma montana*), desert bitterbrush (*Purshia glandulosa*), desert almond (*Prunus fasciculata*), and big sagebrush (*Artemisia tridentata*). Other areas return to pure stands of snakeweed (*Xanthocephalum microcephal* or big sagebrush. Even though desert blackbrush is not a preferred shrub, widescale burning is not recommended as a desirable management policy for this type (Bowns and West 1976). The vegetation that may follow is too unpredictable.

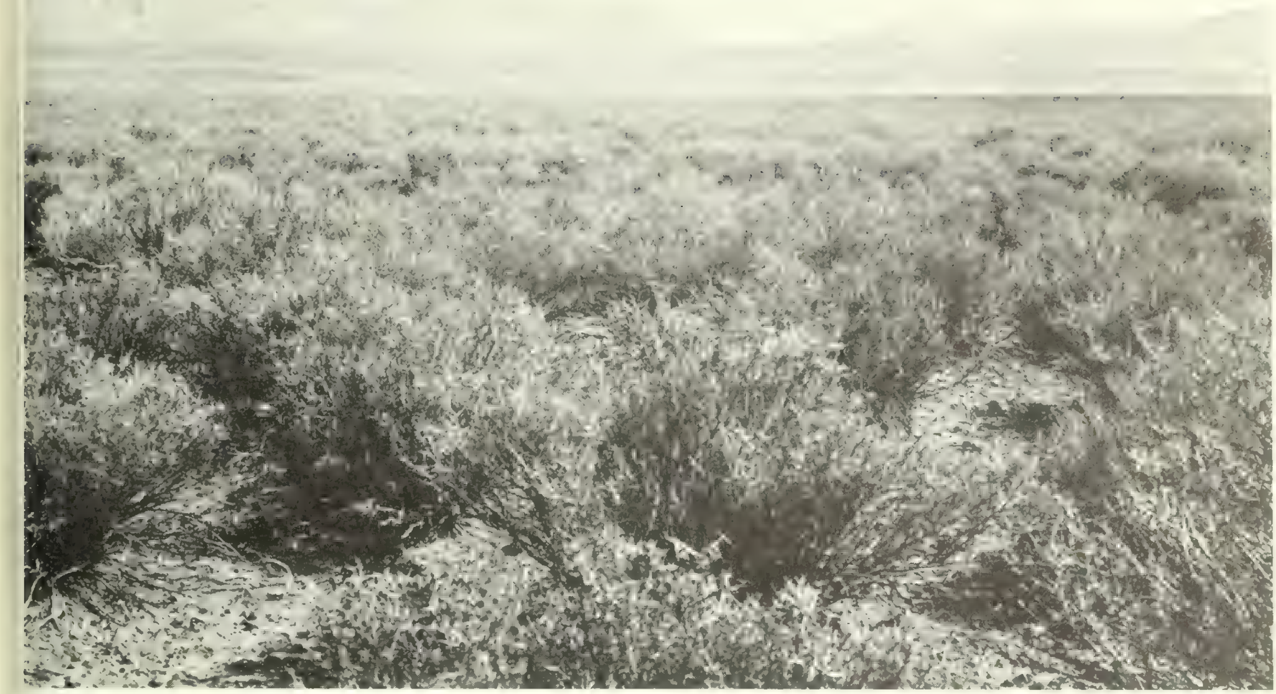


Figure 8.--Typical view of a pure stand of blackbrush. Note the absence of herbaceous vegetation. (Utah State University photo by James E. Bowns)

PRESCRIPTION GUIDES

Prescription guides have not been developed for the semidesert grass-shrub type. Cable (1967) and Dwyer (1972) have reported the conditions under which they burned. Cable conducted burns on areas with 300 to 600 lb/acre (337 to 786 kg/ha) of fine fuel when air temperature was 77°F (25°C), relative humidity was 15 to 18 percent, and wind was 3 to 6 mi/h (5 to 10 kn/h). In heavier fuel (2,840 to 3,570 lb/acre [3 191 to 4 011 kg/ha]), Dwyer (1972) burned when air temperature was 85° to 96°F (29° to 36°C), relative humidity was 5 to 20 percent, and wind was very slight.

Recommendation: Don't try to burn with less than 600 lb/acre (674 kg/ha) of fine fuel unless a good stand of burroweed is present to help carry the fire. Doze a fireline 10 to 12 ft (3.0 to 3.7 m) wide around the area to be burned. About 600 to 3,000 acres (243 to 1 215 ha) would be a reasonable unit to burn. Strip headfire a 100-ft (30-m) strip on the leeward sides of the planned burning during evening or morning hours in May or June when weather conditions are approximately as follows: air temperature 70°F (21°C), relative humidity 15 to 30 percent, and wind less than 8 mi/h (13 km/h). If the fire continues to back up beyond the 100-ft (30 m) strip, put it out with a pumper. Headfire the remainder of the area when air temperature is 70° to 90°F (21° to 32°C), relative humidity is 10 to 40 percent, and windspeed is 8 to 15 mi/h (13 to 24 km/h).

Quanity of fuel will have a very pronounced effect on fire behavior. Thus, one should do some test burning to approximate the conditions under which fire can be conducted safely and yet accomplish the desired objectives. In heavy fuels such as tobosagrass or sacaton, a backing fire may be adequate to accomplish objectives. However, where fuel is light (less than 1 000 kg/ha), a windspeed in excess of 8 mi/h (13 km/h) will be necessary for the fire to carry through the fine fuel.

MANAGEMENT IMPLICATIONS

The southern desert grass-shrub type is a delicate ecosystem with wide swings in herbage yields because severe droughts are common. Moreover, droughts frequently last 2 or 3 years. When moderate to heavy grazing is superimposed on black grama ranges, grass competition and vigor of grasses are drastically reduced (Canfield 1939). These factors favor high mortality of herbs during drought years and the eventual establishme of shrubs following wet years when other climatic factors, such as soil temperature, ar favorable. It appears that use of fire would compound the existing problems on black grama ranges and may not have a place for shrub control on good ranges.

Our problem is to reclaim poor rangelands (predominantly brush), and to properly manage our good rangelands. Poor rangelands cannot be managed with fire. These rangelands must first be restored using other reclamation techniques. However, once the rangelands are in good condition, fire can be used as an effective management tool in special situations during wet weather cycles to control burroweed, broom snakeweed, creosotebush, and young mesquite trees. Fires can also be used to suppress cactus species. Most burning should be done in June, but only following two previous years of better than average plant growth. This is especially important for grasses to recov quickly after burning.

Desirable shrubs that are either favored or not harmed by fire include false-mesquite, velvet-pod mimosa, Wright baccharis, and fourwing saltbush. Wheeler sotol and barrel cactus are easily harmed by fire and should be protected, if possible.

Today, fire should be used only on a selective basis, or in combination with other methods, to achieve specific management objectives in the semidesert grass-shrub type. Fire probably has the greatest value to manage tobosagrass, sacaton, alkali sacaton, and mixed grama ranges. Good black grama grasslands appear to be too delicate to manag with fire. If fire is used, 3 to 4 years rest might be required after the burn.

STATE-OF-THE-ART

Considerable fire research has been done in the semidesert grass-shrub type, but most observations and research have been concentrated in southeastern Arizona. In southern New Mexico, a drier climate, relatively little fire research has been attempte because it was never thought to have played a very important role in the maintenance of southern desert grasslands (Buffington and Herbel 1965). Moreover, now that honey mesquite has invaded many of the sandy sites, fire has no value to restore the sites to black grama grasslands because there is not enough fine fuel to carry a fire.

Since black grama, which is intolerant of fire, was such an important grass in southern desert grasslands over the entire region, long-term research is needed to determine whether fire every 10 years or less frequently could have kept mesquite suppressed. Maybe fire never played a significant role in black grama grasslands, but this question needs to be answered. The following specific questions need to be answere In what kind of years do mesquite seedlings germinate and become established? How rapidly do these young trees grow under different degrees of grass competition? How easily are trees of specific ages killed? How does the interaction of age of mesquite tree, grass competition, drought, fire, and rabbits affect mesquite growth and seed production?

Cover of black grama fluctuates widely with droughts (Nelson 1934), and most of our fire effects data are confounded with drought and grazing. Fire effects need to be evaluated alone and in combination with drought and grazing. This is important to determine how much fire, drought, and grazing black grama can tolerate. Based on Canfield's (1939) clipping research, light grazing should be the severest grazing treatment that can be used with fire on black grama ranges, if fire can be used at all.

Jackrabbits appear to have been a significant factor in keeping young mesquite trees suppressed in healthy stands of grass (Humphrey 1958). Thus, the preferred dietary balance of jackrabbits and their interaction with other environmental factors in good stands of grass should be carefully studied.

Forb data are minimal in the literature. This is because forbs are insignificant when total herbaceous yield is considered. Because we have to be concerned about the total ecosystem, however, we need better data on forb species to evaluate the impact of our management systems on wildlife. Many wildlife species only need a small amount of specific forb species to exist in certain habitats.

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APPENDIX

SUMMARY OF FIRE EFFECTS DATA BY SPECIES

Table 1.--*Summary of fire effects on major grass species*

Species	Response to fire	Recovery time	Remarks
		Years	
Alkali sacaton) Sacaton)	Tolerant	2-4	Basal area recovers in 2 years, but only 54 percent of height recovers in 2 years.
Annual grasses			
Needle grama) Sixweeks threeawn)	Favored	1	Double their yields the first growing season after burning with average or better than average precipitation. Yields remain the same if precipitation is below average.
Arizona cottontop	Tolerant	1-3	Cover or yields may be reduced 40 percent if precipitation is below average, but recovers the first year if precipitation is average or better.
Black grama	Not tolerant	3-8	Basal area of black grama is reduced 90 percent by hot June fires and remains reduced 78 percent at the end of the first growing season when precipitation is above average. It may need 3 or 4 years rest after a burn before light grazing can be resumed.
Bush muhly	Not tolerant	Unknown	Observations based on very limited data (Humphrey 1949).
Galleta	Tolerant	2	Recovers 75 percent of its original growth the first year after a burn.
Lehmann lovegrass	Tolerant	1-2	Large bunchgrasses can be severely damaged, but seedlings of this species quickly reestablish on the burned area.
Rothrock grama	Favored	1-2	May be reduced as much as 30 percent at the end of the first growing season, but recovers fully with average or better than average summer precipitation.
Tall threeawns	Moderately tolerant	2-3	Original basal cover is generally reduced 30 to 50 percent.
Tanglehead	Tolerant	1-3	Same as for Arizona cottontop.
Tobosagrass	Tolerant	1-3	Yield can be reduced 40 to 70 percent if burned during dry years, but will hold its own if summer precipitation after the burn is average.

Table 2.--*Summary of fire effects on forb and cactus species*

Species	Response to fire	Recovery time	Remarks
		Years	
Forbs			
Amaranthus *Ambrosia* *Chenopodium* *Convolvulus* *Ipomaea* *Portulaca* *Solidago*	Favored	1	Cover of a mixture of these forbs increased 60 percent above the control at the end of the first growing season in southeastern Arizona and remained at this level at the end of the second year after burning.
Cacti			
Barrel cactus	Not tolerant	>15	Reduced 65 percent after burning.
Cane cholla	Moderately tolerant	15	Reduced 45 percent after burning.
Jumping cholla	Moderately tolerant	10	Reduced 50 percent after burning.
Pricklypear	Moderately tolerant	15	Reduced 30 percent after burning.

Table 5.--Summary of fire effects on shrub species

Species	Response to fire	Recovery time	Remarks
		Years	
Algerita	Tolerant	10-15	Vigorous sprouter.
Blackbrush	Not tolerant	28	Nonsprouter. Seedlings reestablish on burned areas very slowly.
Broom snakeweed	Not tolerant	5-10	Ninety-five percent mortality, but reestablishes itself with seedlings following wet winters and springs.
Burroweed	Not tolerant	10-20	Mortality is 95 to 100 percent. After 6 years 25 to 30 percent of the preburn density has recovered. After 15 years, burroweed exceeded preburn densities in one study but had failed to reinvade in another. However, if burns are followed by wet winter-spring periods new stands can become reestablished rather quickly.
Catclaw	Tolerant	10-15	Vigorous sprouter.
Creosotebush	Not tolerant	Unknown	Very susceptible to hot June fires, but some resprouting takes place when burned during other months of the year. A weak sprouter.
False-mesquite	Very tolerant	2	Fully recovers by second year after burning and almost doubles by third year after burning.
Fourwing saltbush	Tolerant	2-5	Vigorous sprouter.
Graythorn	Harmed	Unknown	Can be killed by fire (Thornber 1907), but no research studies have been conducted on this species.
Honey mesquite Velvet mesquite)	Tolerant	20-30	Young plants are easily killed, but both species are vigorous sprouters. On upland sites two successive burns can kill 27 percent of the large trees, but on bottomland sites mesquite is very tolerant to fire. Large trees of velvet mesquite appear to be more susceptible to fire than honey mesquite.
Mormon tea	Harmed	Unknown	Based on limited observations by Thornber (1907).
Larchleaf goldenweed	Not tolerant	Unknown	Ninety percent of the plants will be killed by hot fires and 20 percent will be killed by light fires.
Ocotillo	Not tolerant	Unknown	Sixty-seven percent died in severe burns, 40 percent in moderate burns, and 50 percent in light burns.
Paloverde	Not tolerant	Unknown	Humphrey (1949) reported a 90 percent mortality following a wildfire.
Skunkbush sumac	Tolerant	10-15	Vigorous sprouter.
Velvet pod mimosa	Very tolerant	Unknown	Very few plants died on severe burns and no plants died on light and moderate burns.
Wheeler sotol	Not tolerant	Unknown	Ninety-seven percent of the plants died in severe burns, but all plants survived in light and moderate burns.
Winterfat	Tolerant	2-5	Vigorous sprouter.
Wright baccharis	Tolerant	Unknown	Appears to be unaffected by fire (Humphrey 1949).
Yucca	Tolerant	2-5	Very hot fires may cause 25 percent mortality, but generally few plants die following fire.

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1980. The role and use of fire in the semidesert grass-shrub type. USDA For. Serv. Gen. Tech. Rep. INT-85, 24 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

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cludes, southeastern Arizon[illegible]
western Texas where grassla[illegible]
once prevalent. Section[illegible]
area and vegetation, possible role of fire, fire effects data prescription guides, state-of-the-art, and management implications.

KEYWORDS: Semidesert; grass-shrub; desert grassland; fire ecology; prescribed bur[illegible]

Wright, A. Henry
1980. The role and use of fire in the semides[illegible]
type. USDA For. Serv. Gen. Tech. Rep. INT-[illegible]
Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Summarizes current knowledge about the effect of fire on vegetation in the semidesert grass-shrub type. Coverag[illegible]
cludes, southeastern Arizona, southern New Mexico, and [illegible]
western Texas where grasslands in the southern deser[illegible]
once prevalent. Sections presented include descri[illegible]
area and vegetation, possible role of fire, fire [illegible]
prescription guides, state-of-the-art, and management implications.

KEYWORDS: Semidesert; grass-shrub; desert grassland; fire ecology; prescribed burning; fi[illegible]

The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

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